

# Machine Intelligence

## Lecture 1: Introduction to MI and Agents

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## Teacher

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## Literature

D. Poole and A. Mackworth: *Artificial Intelligence. Foundations of Computational Agents* (2nd edition)

`http://artint.info/`

## Course Homepage

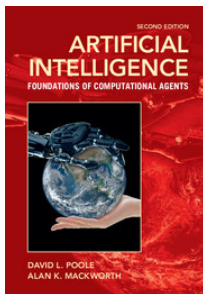
Can be found under Moodle

## Times

- Wednesdays, 8.15-12.00: Exercises 8.15-10.00, Lecture 10.15-12.00
- Extended exercise sessions: Thursdays 12.30-16.15.

## Exam

Exam in January



Several reasons, but:

*We decided that it is better to clearly explain the foundations upon which more sophisticated techniques can be built, rather than present these more sophisticated techniques. This means that a larger gap may exist between what is covered in this book and the frontier of science. But it also means that the student will have a better foundation to understand current and future research.*

## Topics:

- Introduction
- Problem solving as search
- Constrained satisfaction problems
- Logic-based knowledge representation
- Representing domains endowed with uncertainty.
- Bayesian networks
- Machine learning
- Planning
- Reinforcement learning
- Multi-agent systems

After having followed the course you should

- have knowledge about basic techniques within the field of machine intelligence and computational agents.
- be able to apply key machine intelligence techniques to a specific problem domain.
- be able to reason about computational agents that can operate in domains of varying complexity.

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... and be well-prepared for the aMI course and the machine intelligence specialization!

AI

## The Turing Test



A.M. Turing: “Computing Machinery and Intelligence”, *Mind* Vol.59 (1950). Proposes an *imitation game*, which (slightly modified) has become known as the *Turing test*:

An *interrogator* is connected via one terminal to a real person, and by another terminal to a computer (both in another room). The interrogator does not know which terminal is connected to the machine. He or she can perform on both terminals a (natural language) dialogue with whatever is at the other end of the line. The machine passes the Turing test, if the interrogator is not able to identify, which terminal is connected to the machine.

⇒ The Turing test tests observable behavior, not cognitive processes!



## Achievements: Deep Blue



- 30 IBM RS/6000 processors
- 480 custom chess processors
- able to examine 200 million moves per second
- database of 700.000 grandmaster games
- endgame database (covering all 5 piece positions)

Results:

1996:	Kasparov 4	Deep Blue 2
1997:	Kasparov 2.5	Deep Blue 3.5

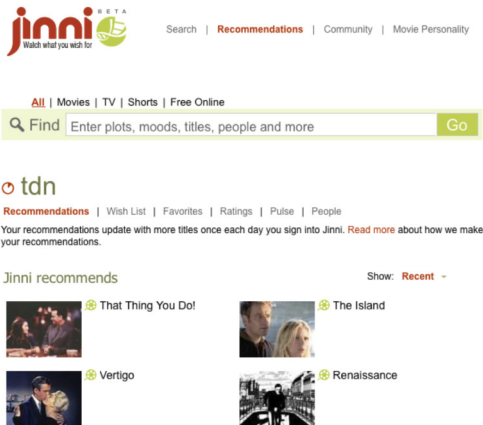
## ... two decades later

AlphaGo was developed by Google Deepmind to play Go. In March 2016 it played a five game match against Lee Sedol with a final score of 4-1 in favor of AlphaGo.



- AlphaGo combines Monte Carlo tree search with (deep) artificial neural networks.

## Systems for recommending items that users are likely to find interesting



The screenshot displays the Jinni website interface. At the top, the Jinni logo is accompanied by the tagline "Watch what you wish for" and a navigation menu with links for Search, Recommendations, Community, and Movie Personality. Below this, a secondary navigation bar includes links for All, Movies, TV, Shorts, and Free Online. A search bar with the placeholder text "Enter plots, moods, titles, people and more" and a "Go" button is present. The main content area features a "tdn" (Today's Daily News) section with a "Recommendations" link and a brief description of the recommendation system. Below this, a "Jinni recommends" section displays a grid of movie recommendations, each with a thumbnail image and a title. The recommendations shown are "That Thing You Do!", "The Island", "Vertigo", and "Renaissance". A "Show: Recent" dropdown menu is located to the right of the recommendations grid.

**jinni** BETA  
Watch what you wish for

Search | **Recommendations** | Community | Movie Personality

**All** | Movies | TV | Shorts | Free Online

Find Enter plots, moods, titles, people and more Go


**tdn**


**Recommendations** | Wish List | Favorites | Ratings | Pulse | People


Your recommendations update with more titles once each day you sign into Jinni. [Read more](#) about how we make your recommendations.


Jinni recommends

Show: **Recent**

 That Thing You Do!

 The Island

 Vertigo

 Renaissance

The image shows a screenshot of the Netflix Prize website. At the top, there is a yellow banner with the text "Netflix Prize" in white. To the right of the banner is a red stamp that says "COMPLETED". Below the banner is a navigation bar with links: Home, Rules, Leaderboard, and Update. The main content area is dark and shows a blurred view of the Netflix website interface, including sections like "Movies For You" and "You really liked it". Overlaid on the right side of the screenshot is a white box with a blue border containing the text "Congratulations!".

## Netflix Prize

Home Rules Leaderboard Update

### COMPLETED

### Congratulations!

The Netflix Prize sought to substantially improve the accuracy of predictions about how much someone is going to enjoy a movie based on their movie preferences.

On September 21, 2009 we awarded the \$1M Grand Prize to team "BellKor's Pragmatic Chaos". Read about [their algorithm](#), checkout team scores on the [Leaderboard](#), and join the discussions on the [Forum](#).

We applaud all the contributors to this quest, which improves our ability to connect people to the movies they love.

# Jeopardy!: Watson

In 2011, Watson beat Brad Rutter, the biggest all-time money winner on Jeopardy!, and Ken Jennings, the record holder for the longest championship streak (75 days)



- Application of natural language processing, information retrieval, knowledge representation and reasoning, and machine learning
- Made up of a cluster of 90 IBM Power 750 servers with a total of 2880 POWER7 processor cores and 16 Terabytes of RAM. Each Power 750 server uses a 3.5 GHz POWER7 eight core processor, with four threads per core.

Taken from Wikipedia, August 25th, 2011

# Jeopardy!: Watson

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New developments Watson has since evolved into a more general purpose cognitive platform (using natural language processing and machine learning) with applications in e.g. health care.



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## AI in computer games (e.g. Starcraft)



<http://eis.ucsc.edu/StarCraftAICompetition>

## AI in computer games (e.g. Starcraft)



### Algorithms Discover Build Order From Hell

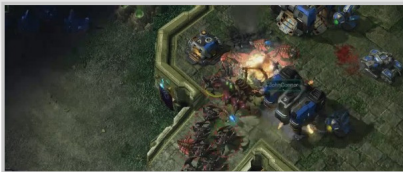
By [Quintin Smith](#) on November 2nd, 2010 at 1:04 pm.

[Tweet](#)

91

[Submit](#)

[Like](#)



This is mad. Over on StarCraft 2 forum [Teamliquid](#), a poster who goes by Lomilar has been **talking** about **a program** he's coded called EvolutionChamber. It uses genetic algorithms to find powerful build orders, meaning his program takes a population of build orders, kills off the useless ones, and has the most successful ones reproduce asexually to create a new population, which tests itself again, and so on. I'm taking all this from [this](#) blog post by programmer Louis Brandy, wherein he breaks down what Lomilar's done so that lay folk can understand it.

EvolutionChamber's already come up with one ludicrous build order, which I've posted beneath the jump.

```
10 extractor-trick to 11
11 overlord
11 spawning pool
15 extractor
16 queen (stop drones here)
18 overlord
18 roach warren
17 overlord (yes, two)
spawn-larva on queen when she pops
roach x7
```

**AIIDE 2011  
StarCraft  
Competition**

<http://eis.ucsc.edu/StarCraftAICompetition>



The TrueSkill ranking system is a skill based ranking system for Xbox Live developed at Microsoft Research.



<https://research.microsoft.com/en-us/projects/trueskill/>

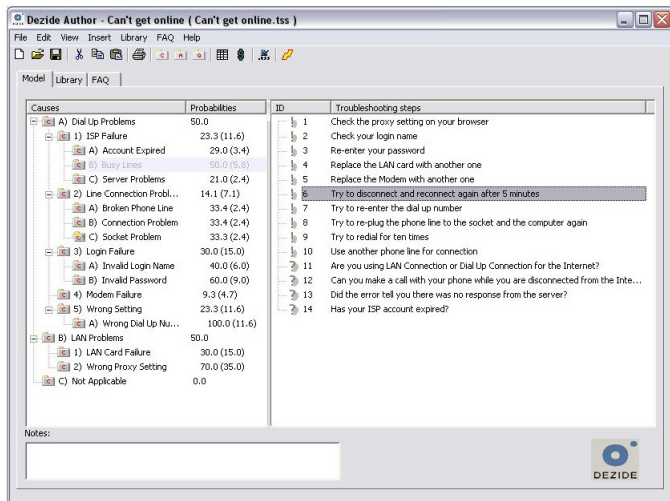


Figure borrowed from Dezide's homepage ([www.deczide.com](http://www.deczide.com))

## Achievements: Automatic Translation

Google translate:



## Achievement: DARPA grand challenge 2005

Competition for autonomous vehicles: navigate 132 miles through desert terrain (route specified by approx. 3000 “waypoints”). 5 out of 23 vehicles completed the task. Winner: *Stanley* of Stanford Racing Team in 6h 53m (19.2 mph).



- 7 Pentium M computers
- Sensors: 4 laser range finders, 1 radar system, 1 stereo camera pair, 1 monocular vision system, GPS, inertial measurement unit, wheel speed.

## Achievement: DARPA grand challenge 2005

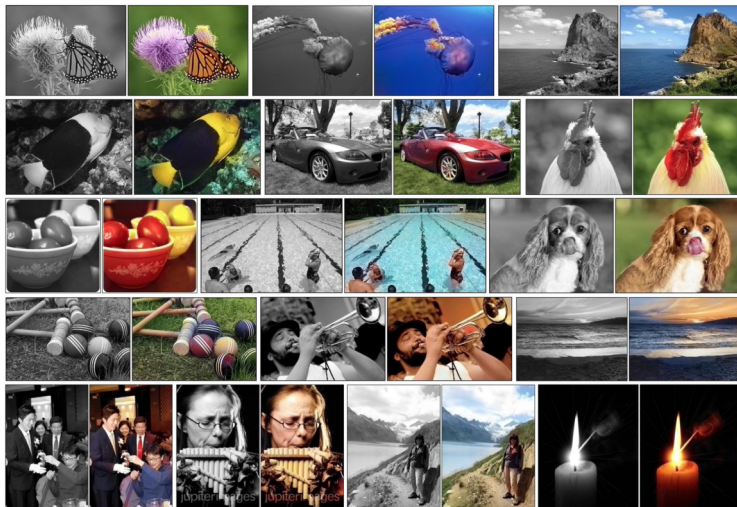


...t terrain (route specified  
Winner: *Stanley* of

...ir, 1 monocular vision

June 2016: approx. 2.8 mill. km. autonomous driving.

## Colorization of images

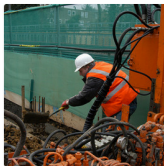


Zhang, Isola, Efros. Colorful Image Colorization. In ECCV, 2016.

## Image captioning



"man in black shirt is playing guitar."



"construction worker in orange safety vest is working on road."



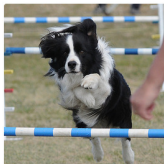
"two young girls are playing with lego toy."



"boy is doing backflip on wakeboard."



"girl in pink dress is jumping in air."



"black and white dog jumps over bar."



"young girl in pink shirt is swinging on swing."



"man in blue wetsuit is surfing on wave."

Andrej Karpathy, Li Fei-Fei, Deep Visual-Semantic Alignments for Generating Image Descriptions, CVPR 2015

- Medical diagnosis and advisory systems
- Information processing and filtering,
- Display of information for time-critical decisions
- Spam filtering
- Optical character recognition
- Profiling/Credit scoring: profiling customers
- Bioinformatics
- Real estate: Prediction of house prices
- Computer networks: intrusion detection
- Alert and monitoring systems
- Speech recognition
- Face recognition, image annotation
- Action recognition (in video sequences)
- ...



## Turing Test (Loebner Competition)

- Loebner Competition: (Non-scientific) competition for computer systems performing under Turing Test conditions.
- <http://www.pandorabots.com/pandora/talk?botid=f5d922d97e345aa1>

## Online help

- Combine natural language interface with expert knowledge.
- Restricted Domain (Geography): CHAT-80 (1982)
- Broad Domain (“all factual knowledge”): Wolfram Alpha  
<http://www.wolframalpha.com/>

## A “computational knowledge engine” ?

*All one needs to be able to do is to take questions people ask in natural language, and represent them in a precise form that fits into the computations one can do.*

*[...]*

*I wasn't at all sure it was going to work. But I'm happy to say that with a mixture of many clever algorithms and heuristics, lots of linguistic discovery and linguistic curation, and what probably amount to some serious theoretical breakthroughs, we're actually managing to make it work. [Stephen Wolfram, <http://blog.wolfram.com>, March 5, 2009]*

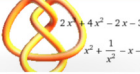
*Think about that for a minute. It computes the answers. Wolfram Alpha doesn't simply contain huge amounts of manually entered pairs of questions and answers, nor does it search for answers in a database of facts. Instead, it understands and then computes answers to certain kinds of questions. [Nova Spivack on [twine.com](http://twine.com)]*

## Some queries to try:

### Examples by Topic


What can you ask Wolfram|Alpha about?

#### MATHEMATICS




Elementary Math · Numbers · Arithmetic · Plotting & Graphics · Algebra · Equation Solving · Polynomials · Simplification · Matrices & Linear Algebra · Geometry · Coordinate Geometry · Plane Geometry · Trigonometry · Calculus · Differential Equations · Discrete Math · Number Theory · Applied Math · Logic & Set Theory · Boolean Algebra · Functions · Domain & Range · Definitions · ...

#### WORDS & LINGUISTICS



Word Properties · Dictionary Lookup · Word Puzzles · Anagrams · Languages · Document Length · Morse Code · Soundex · Number Names · Character Encodings · ...

#### UNITS & MEASURES



Conversions · Calculations · Comparisons · Dimensional Analysis · Industrial & Construction · Batteries · Bulk Materials · Paint · Freight Containers · Display Formats · Ring Sizes · Shoe Sizes · ...

#### STEP-BY-STEP SOLUTIONS

PRO

Move terms with x to the left hand side.


Subtract 2 x from both sides:

$$(4x - 2x) - 6 = (2x - 2x) + 8$$

Next step Show all steps 15

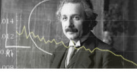
Physics Formulas · Chemistry · Arithmetic · Number Theory · Statistics · Intercepts · Trigonometry · Algebra · Calculus · Discontinuities · Differential Equations · Linear Algebra · Mathematical Induction · ...

#### STATISTICS & DATA ANALYSIS



Descriptive Statistics · Statistical ...


#### PEOPLE & HISTORY



People · Genealogy · Names · Occupations · Political Leaders · Historical Events · Historical Periods · Historical Countries · Historical Numerals · Historical US Money · Inventions · ...

#### DATES & TIMES

Tokyo Chicago, Illinois



4:26:37 am JST 2:26:37 pm CDT

Date Computations · Time Zones · Calendars · Holidays · Geological Time · Birthstones · Birth Flowers · Wedding Anniversaries · ...

#### DATA INPUT

PRO

cities-types-currency

City	Type	Currency
Chicago	City	\$
Hartford	City	\$
Indianapolis	City	\$
Los Angeles	City	\$

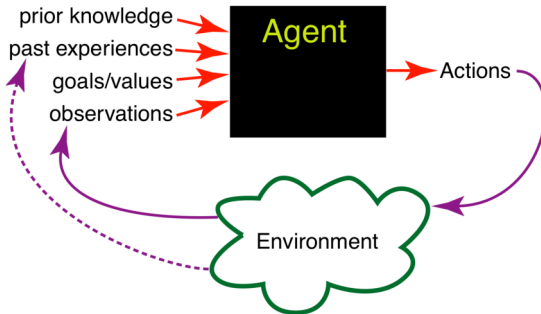
Automatic Analysis · Statistical Analysis · Time Series Analysis · Geographic Data · Data Visualization · ...

# The Agent view of AI

# AI and Agents

*AI is the field that studies the synthesis and analysis of computational agents that act intelligently. [PM, p.3]*

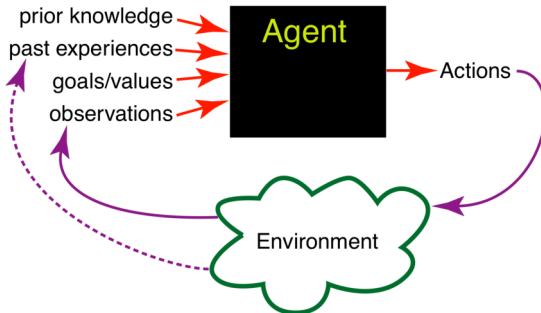
*A coupling of perception, reasoning, and acting comprises an agent. [PM, p.10]*



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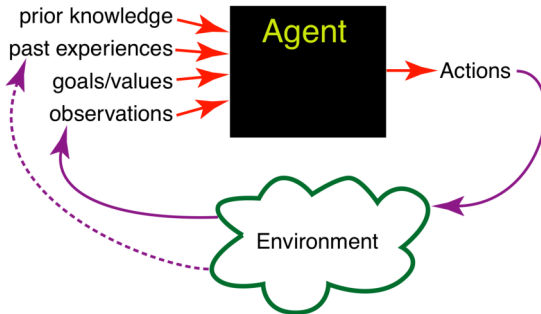


Some special flavors:

- Autonomous agents
- Intelligent agents
- Software agents
- Multi-agent systems

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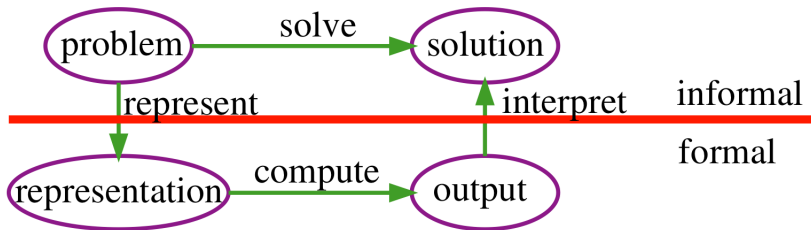


Some special flavors:

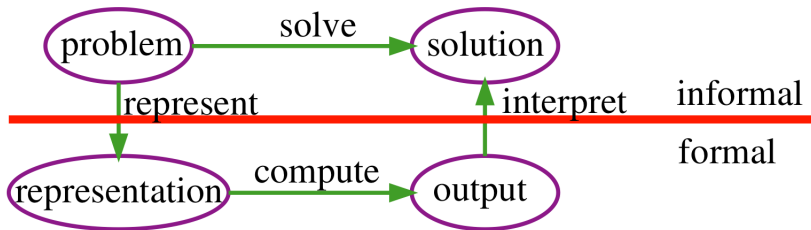
- Autonomous agents
- Intelligent agents
- Software agents
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What is *not* an agent?

- perception ~ input
- reasoning ~ computation
- acting ~ output
- ~ "agent" a design metaphor, not a strict technical concept

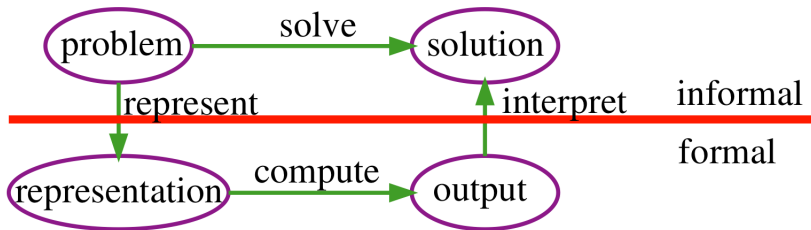






A *representation* should be:

- Sufficiently rich to encode the required knowledge.
- Be “close” to the problem.
- Amenable to efficient computation.
- Able to be acquired from people, data, or experience.



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Questions to be considered:

- What is a solution and how good should it be (optimal, satisfying, approximately, probable)?
- How can the problem be represented?
- How can an output be computed (what properties should a solution have)?

What is the highest mountain in the United States?

solve (human)

Mt. McKinley

represent

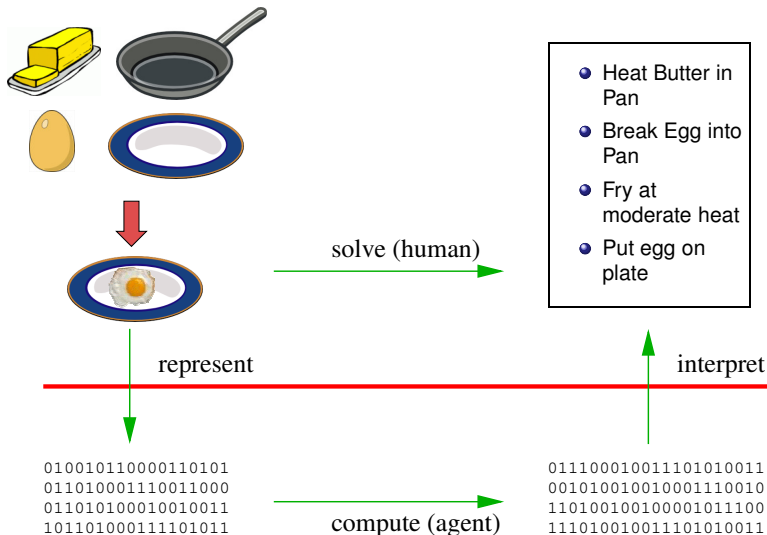
interpret

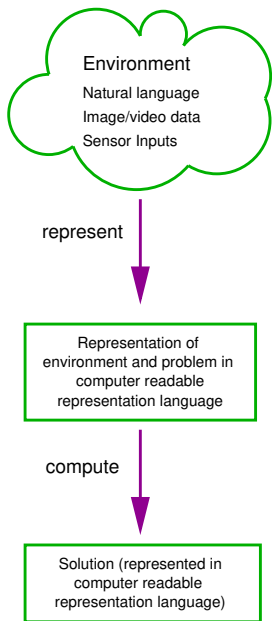
highest mountain

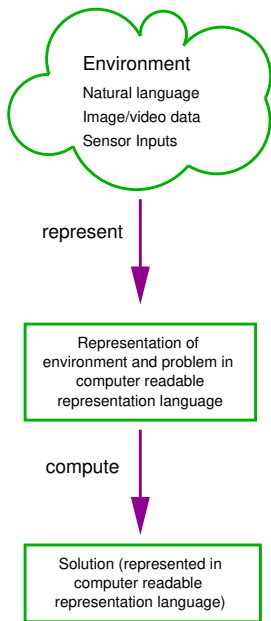
in United States

compute (agent)

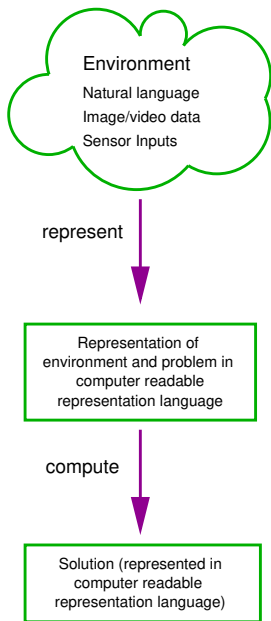
1	Mount McKinley	20 322 ft	<input type="text"/>
2	Mount auser	18 212 ft	<input type="text"/>
3	Mount Saint Elias	18 009 ft	<input type="text"/>
4	Mount Foraker	17 402 ft	<input type="text"/>
5	Bona	16 421 ft	<input type="text"/>







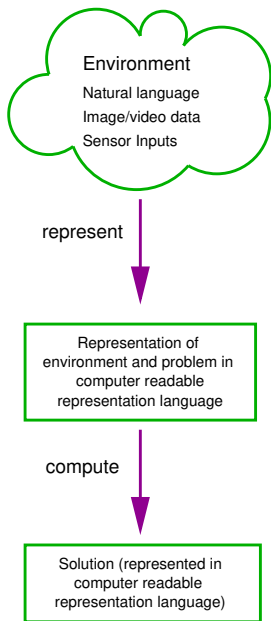
**2.** What formal representation languages can be used?



1. How to interpret input/observations from environment?

2. What formal representation languages can be used?

3. How to solve problems in the given representation language?



1. How to interpret input/observations from environment?

*Natural Language Processing*  
*Computer Vision*  
...

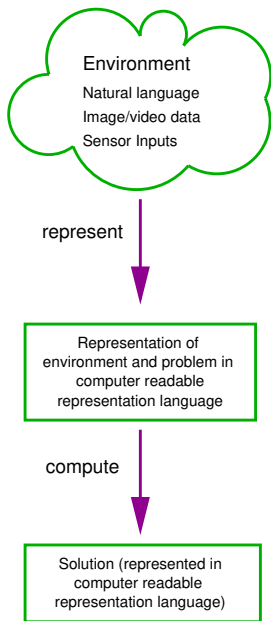
2. What formal representation languages can be used?

*Knowledge Representation*

3. How to solve problems in the given representation language?

*Problem Solving*  
*Automated Reasoning*





1. How to interpret input/observations from environment?

*Natural Language Processing*  
*Computer Vision*  
...

2. What formal representation languages can be used?

*Knowledge Representation*

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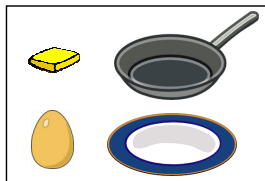
*Problem Solving*  
*Automated Reasoning*

In this course the focus is on **2.** and **3.!**

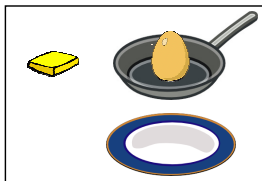
## Representing the problem

We consider 3 representation schemes

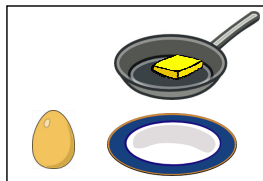
- State based
- Feature based
- Relational



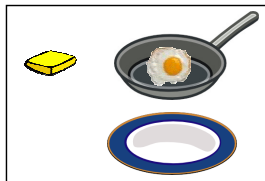
State 01



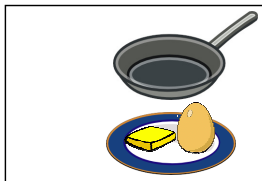
State 04



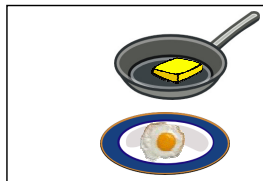
State 08



State 12



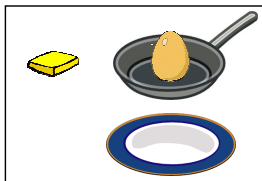
State 14



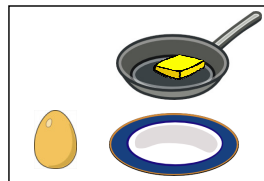
State 18



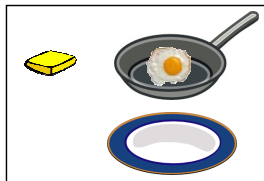
*egg=whole,  
butter\_in=table,  
egg\_in=table*



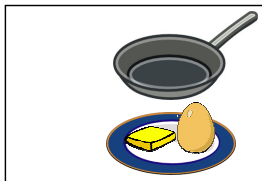
*egg=whole,  
butter\_in=table,  
egg\_in=pan*



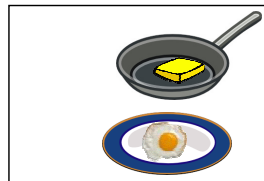
*egg=whole,  
butter\_in=pan,  
egg\_in=table*



*egg=broken,  
butter\_in=table,  
egg\_in=pan*



*egg=whole,  
butter\_in=plate,  
egg\_in=plate*

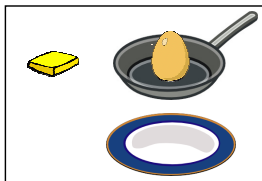


*egg=broken,  
butter\_in=pan,  
egg\_in=plate*

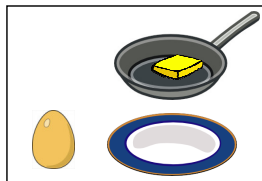
30 binary features represent  $2^{30} = 1.073.741.824$  states.



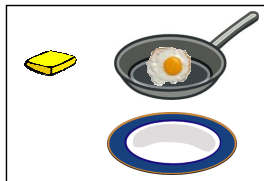
*state(egg,whole),  
in(butter,table),  
in(egg,table)*



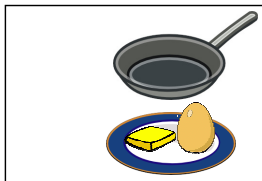
*state(egg,whole),  
in(butter,table),  
in(egg,pan)*



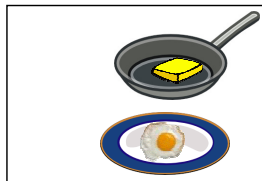
*state(egg,whole),in(butter,pan),  
in(egg,table)*



*state(egg,broken),  
in(butter,table),  
in(egg,pan)*



*state(egg,whole),  
in(butter,plate),  
in(egg,plate)*



*state(egg,broken),  
in(butter,pan),  
in(egg,plate)*

1 binary relation and 100 individuals give  $100^2 = 10.000$  boolean features, or  $2^{10000}$  states.

Do we need to distinguish states



*egg=whole,  
butter\_in=table,  
egg\_in=table,  
butter\_position\_to\_pan=left*



*egg=whole,  
butter\_in=table,  
egg\_in=pan,  
butter\_position\_to\_pan=right*

- Not at “recipe level”
- Yes at robot control level: “*move arm to left, grab butter, ...*”
- $\rightsquigarrow$  may need hierarchical description of state space to reason at different levels of abstraction.

## Modularity

- Flat, modular, hierarchical



# Other dimensions of complexity

## Modularity

- Flat, modular, hierarchical

## Planning horizon

- Non-planning, finite, indefinite, infinite

## Modularity

- Flat, modular, hierarchical

## Planning horizon

- Non-planning, finite, indefinite, infinite

## Domain uncertainty

- Fully observable vs. partially observable world.
- Deterministic vs. stochastic.

## Modularity

- Flat, modular, hierarchical

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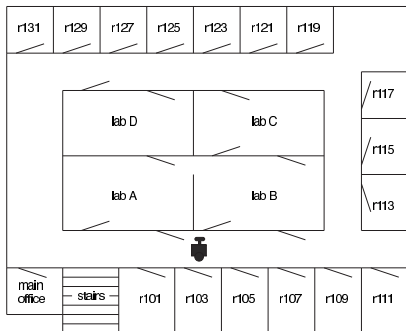
## Learning

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## Computational limits

- Perfect or bounded rationality

# Prototypical Applications



## Inputs:

- Prior knowledge, past experience, goals, observations

## Outputs:

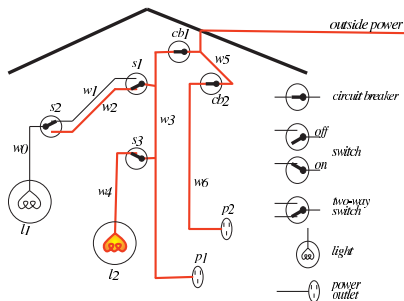
- Motor control, speech, video display

## Complexity issues:

- Hierarchical decomposition
- Planning horizon
- Goals
- Uncertainty
- ...

- Robot can move, pick up and put down objects
- Receives commands (in natural language)
- Can deliver packages, mail, coffee, ...
- Must interpret commands, develop and execute plans for action





## Inputs:

- Prior knowledge, past experience, goals, observations

## Outputs:

- Recommendations on treatments and tests

## Complexity issues:

- Sensing/effect uncertainty
- Knowledge representation
- Goal specification

- Advise a human about system, e.g. diagnose patient, troubleshoot electrical system, automobile, etc.
- Substitute of human expert

## Characteristics

- Automatically buy/sell goods for user/company (possibly at auction)
- Determine good strategy to procure necessary goods in time at best price

## Inputs

- Prior knowledge about goods, past experience, preferences, observations

## Output

- Proposals to the user

## Topics:

- Introduction
- Problem solving as search
- Constrained satisfaction problems
- Logic-based knowledge representation
- Representing domains endowed with uncertainty.
- Bayesian networks
- Machine learning
- Planning
- Reinforcement learning
- Multi-agent systems