Reinforcement Learning

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ENS Cachan - Master 2 MVA

FAIR / Inria

From Psychology to Machine Learning

Decision-making Under Uncertainty

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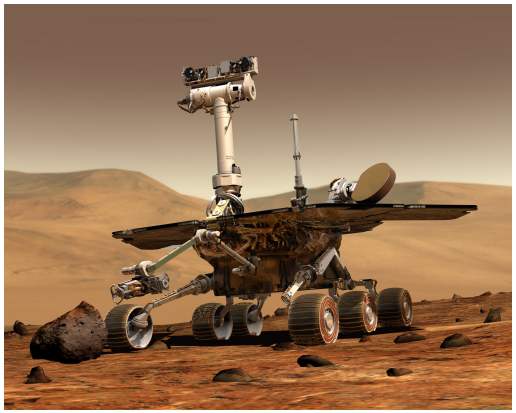

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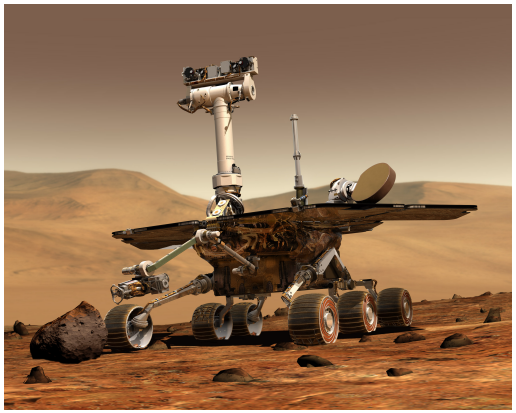

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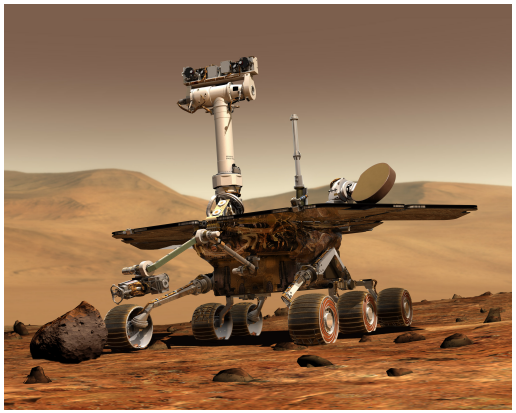


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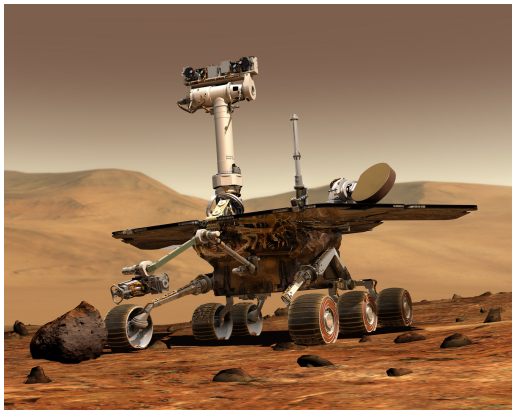

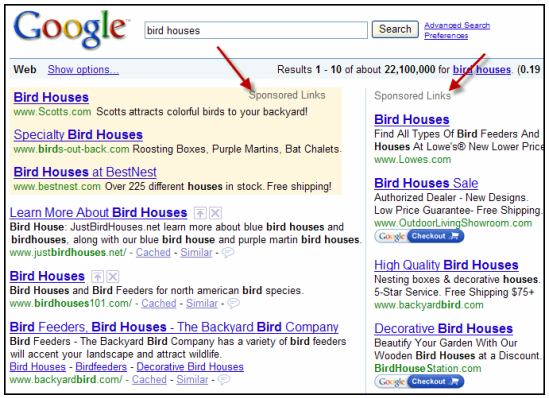

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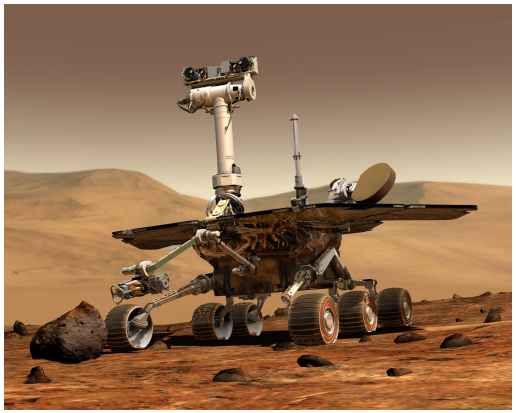

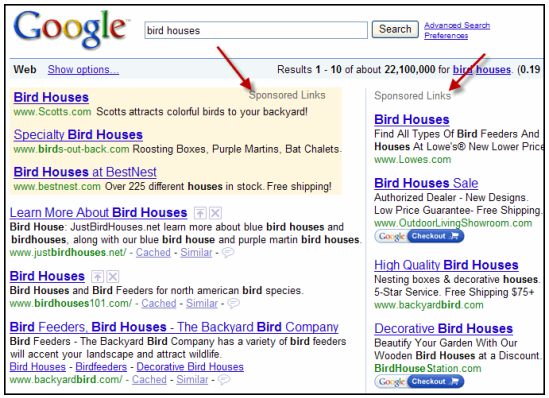

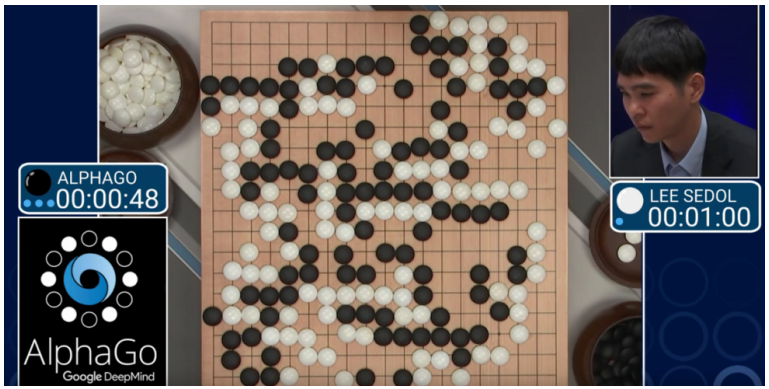

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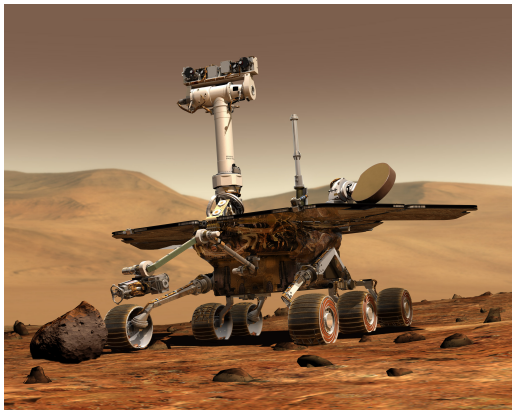
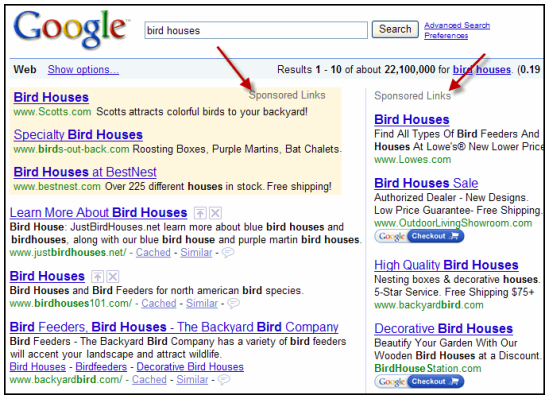
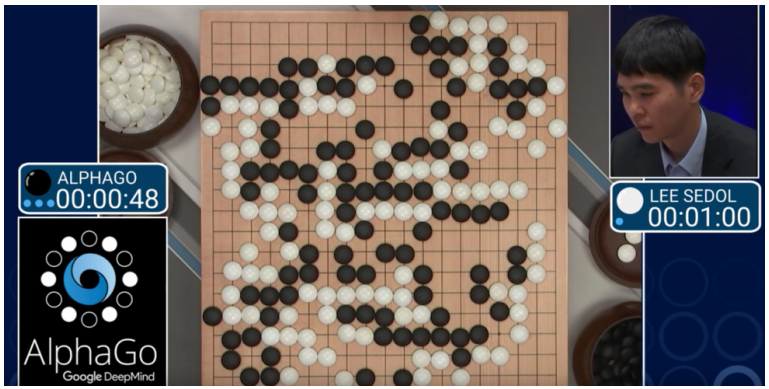






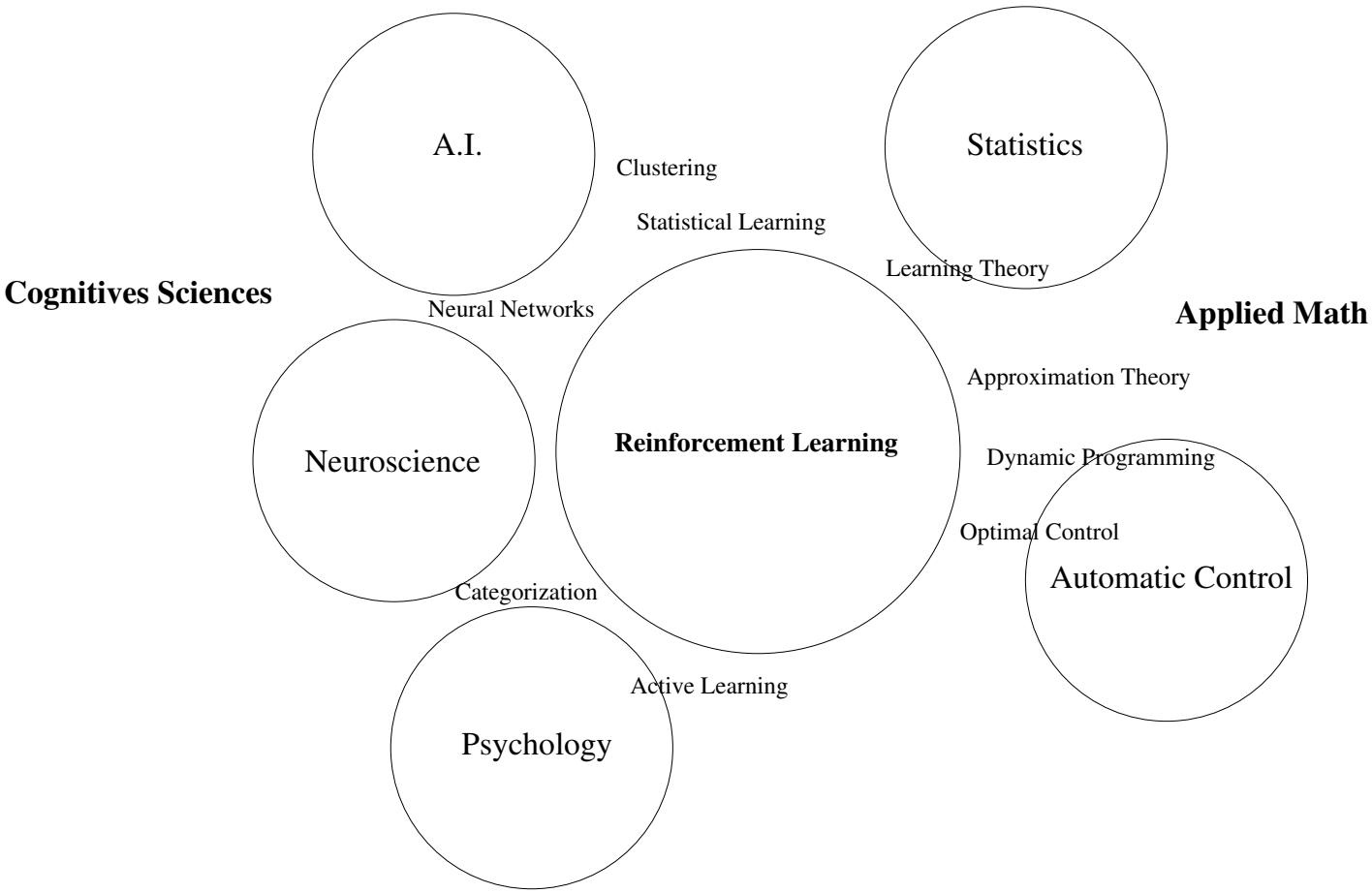
Formal and *rigorous* approach to
the RL's way to decision-making under uncertainty

Reinforcement learning

Reinforcement learning *is learning what to do – how to map situations to actions – so as to* ***maximize*** *a numerical* ***reward*** *signal in an* ***unknown uncertain*** *environment. The learner is not told which actions to take, as in most forms of machine learning, but she must discover which actions yield the most reward by trying them (****trial–and–error****). In the most interesting and challenging cases, actions may affect not only the immediate reward but also the next situation and, through that, all subsequent rewards (****delayed reward****).*

"An introduction to reinforcement learning",
Sutton and Barto (1998).

A Multi-disciplinary Field



See the biannual conference *"Reinforcement learning and decision-making (RLDM)"*

Behavioral (human and animal) Psychology

The law of effect [Thorndike, 1911]

*"Of several responses made to the same situation, those which are accompanied or closely followed by **satisfaction** to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by **discomfort** to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur.*

The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond."

Inspirations at the Basis of RL

Psychology

- *Classical (human and) animal conditioning*: "the magnitude and timing of the conditioned response changes as a result of the contingency between the conditioned stimulus and the unconditioned stimulus" [Pavlov, 1927].
- *Operant conditioning (or instrumental conditioning)*: process by which humans and animals *learn* to behave in such a way as to obtain *rewards* and avoid *punishments* [Skinner, 1938].

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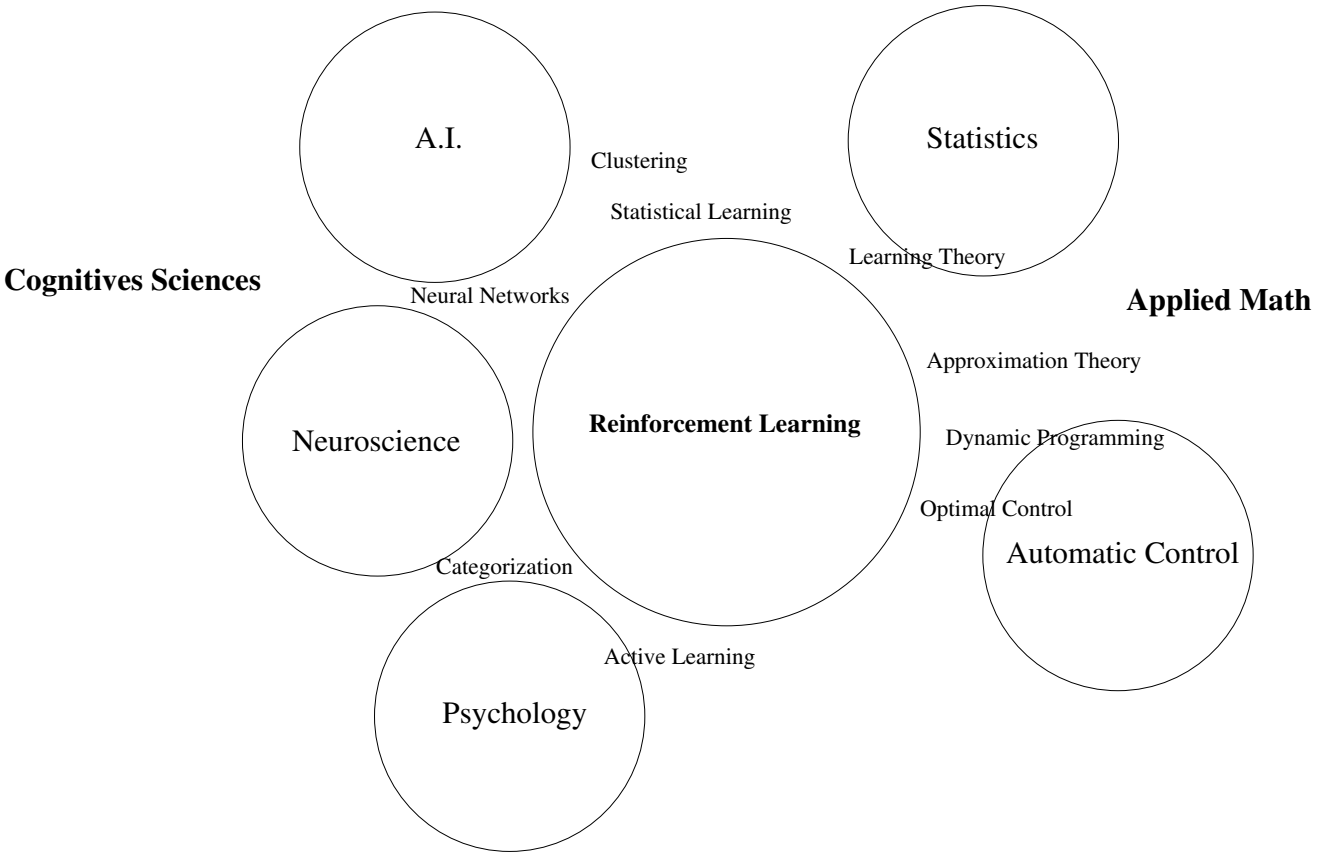
Neuroscience

- *Hebbian learning*: development of formal models of how the synaptic weights between neurons are reinforced by simultaneous activation. *"Cells that fire together, wire together."* [Hebb, 1961].
- *Dopamine and basal ganglia model*: direct link with motor control and decision-making (e.g., [Doya, 1999]).

A Multi-disciplinary Field



In this course: RL is a ***machine learning*** paradigm

A Machine Learning Paradigm

- *Supervised learning:* an expert (*supervisor*) provides examples of the right strategy (e.g., classification of clinical images). *Supervision is expensive.*

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A Machine Learning Paradigm

- *Supervised learning:* an expert (*supervisor*) provides examples of the right strategy (e.g., classification of clinical images). *Supervision is expensive.*
- *Unsupervised learning:* different objects are clustered together by similarity (e.g., clustering of images on the basis of their content). *No actual performance is optimized.*
- *Reinforcement learning:* learning by direct interaction (e.g., autonomous robotics). *Minimum level of supervision (reward) and maximization of long term performance.*

What is RL Capable of?

Videos!

What Will You Be Capable of After this Course?

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None of the Above!

What Will You Be Capable of After this Course?

None of the Above!

But hopefully master everything that is at the basis of them!

Main Topics Covered in the Course

How to *model* an RL problem

- *What:* Markov decision process
- *Tools:* probability, processes, Markov chain

Main Topics Covered in the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

- *What:* Dynamic programming
- *Tools:* fixed point, operators

Main Topics Covered in the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

How to solve *incrementally* an RL problem

- *What:* temporal difference, Q-learning
- *Tools:* stochastic approximation

Main Topics Covered in the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

How to solve *incrementally* an RL problem

How to *efficiently* explore in an RL problem

- *What:* multi-armed bandit problem
- *Tools:* concentration inequalities

Main Topics Covered in the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

How to solve *incrementally* an RL problem

How to *efficiently* explore in an RL problem

How to solve *approximately* an RL problem

- *What:* approximate RL
- *Tools:* supervised learning, optimization

Main Topics Covered in the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

How to solve *incrementally* an RL problem

How to *efficiently* explore in an RL problem

How to solve *approximately* an RL problem

With (simple!) examples from *resource optimization*, *trade execution*, *computer games*, *recommendation systems*.

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