



A Quick Look at the “Reinforcement Learning” course

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ENS Cachan - Master 2 MVA

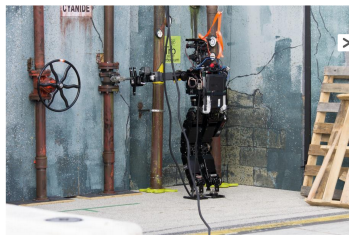
SequeL – INRIA Lille

Why

Why: Important Problems

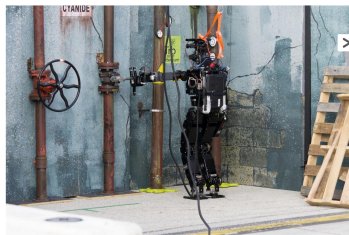
Why: Important Problems

- ▶ Autonomous robotics



Why: Important Problems

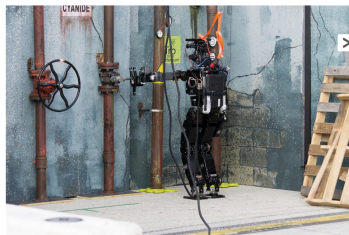
- ▶ Autonomous robotics



- ▶ *Elder care*

Why: Important Problems

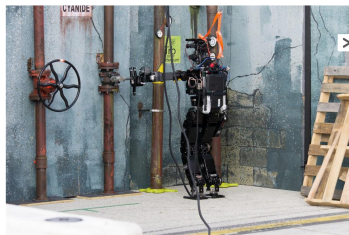
- ▶ Autonomous robotics



- ▶ *Elder care*
- ▶ *Exploration of unknown/dangerous environments*

Why: Important Problems

- ▶ Autonomous robotics



- ▶ *Elder care*
- ▶ *Exploration of unknown/dangerous environments*
- ▶ *Robotics for entertainment*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications



Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications



- ▶ *Trading execution algorithms*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications



- ▶ *Trading execution algorithms*
- ▶ *Portfolio management*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications



- ▶ *Trading execution algorithms*
- ▶ *Portfolio management*
- ▶ *Option pricing*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management



Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management



- ▶ *Energy grid integration*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management



- ▶ *Energy grid integration*
- ▶ *Maintenance scheduling*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management



- ▶ *Energy grid integration*
- ▶ *Maintenance scheduling*
- ▶ *Energy market regulation*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management



- ▶ *Energy grid integration*
- ▶ *Maintenance scheduling*
- ▶ *Energy market regulation*
- ▶ *Energy production management*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems

The image shows a Google search interface for the query "bird houses". The search bar contains "bird houses" and the search button is visible. The results page shows "Results 1 - 10 of about 22,000,000 for bird houses (0.19)". Two red arrows point to the search bar and the results count. The results are divided into "Sponsored Links" and "Organic Results".

Sponsored Links:

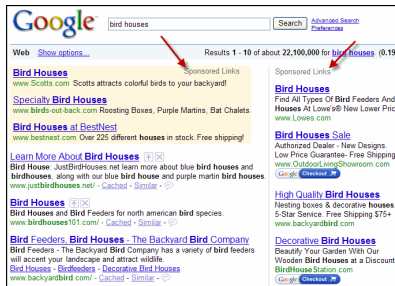
- Bird Houses** - Scotts attracts colorful birds to your backyard! (www.Scotts.com)
- Specialty Bird Houses** - www.birds-out-back.com Roosting Boxes, Purple Martins, Bat Chalets.
- Bird Houses at BestNest** - www.bestnest.com Over 225 different houses in stock. Free shipping!
- Bird Houses Sale** - Authorized Dealer - New Designs. Low Price Guarantee- Free Shipping (www.OutOfdoornLivingShowroom.com)
- High Quality Bird Houses** - Nesting boxes & decorative houses. 5-Star Service. Free Shipping \$75+ (www.backyardbird.com)
- Decorative Bird Houses** - Beautify Your Garden With Our Wooden Bird Houses at a Discount. (BirdHouseStation.com)

Organic Results:

- Learn More About Bird Houses** - JustBirdHouses.net learn more about blue bird houses and birdhouses, along with our blue bird house and purple martin bird houses. (www.justbirdhouses.net/)
- Bird Houses and Bird Feeders for north american bird species.** (www.birdhouses101.com/)
- Bird Feeders, Bird Houses - The Backyard Bird Company** - Bird Feeders - The Backyard Bird Company has a variety of bird feeders will accent your landscape and attract wildlife. (www.backyardbird.com/)

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems



The screenshot shows a Google search for "bird houses" with approximately 22,100,000 results. Two red arrows point to the "Sponsored Links" sections on the left and right sides of the results page. The left sidebar contains several sponsored links for bird houses, including "Bird Houses" from Scotts.com, "Specialty Bird Houses" from birds-out-back.com, "Bird Houses at BestNest" from bestnest.com, "Learn More About Bird Houses" from JustBirdHouses.net, "Bird Houses" from birdhouses101.com, and "Bird Feeders, Bird Houses - The Backyard Bird Company". The right sidebar contains sponsored links for "Bird Houses" from Lowe's.com, "Bird Houses Sale" from OutdoorLivingShowroom.com, "High Quality Bird Houses" from backyardbird.com, and "Decorative Bird Houses" from BirdHouseStation.com.

- ▶ *Web advertising*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems

The screenshot shows a Google search for "bird houses". The search bar contains "bird houses" and the search button is visible. The results page shows "Results 1 - 10 of about 22,100,000 for bird houses (0.19)". Two red arrows point to the search bar and the search button. The results are divided into "Sponsored Links" and "Organic Results".

Sponsored Links:

- Bird Houses** - Scotts attracts colorful birds to your backyard! www.Scotts.com
- Specialty Bird Houses** - www.birds-out-back.com Roosting Boxes, Purple Martins, Bat Chalets.
- Bird Houses at BestNest** - www.bestnest.com Over 225 different houses in stock. Free shipping!
- High Quality Bird Houses** - Nesting boxes & decorative houses. 5-Star Service. Free Shipping \$75+ www.backyardbird.com

Organic Results:

- Learn More About Bird Houses** - www.JustBirdHouses.net learn more about blue bird houses and birdhouses, along with our blue bird house and purple martin bird houses. www.justbirdhouses.net/ - [Cached](#) - [Similar](#) - [🔄](#)
- Bird Houses** - Bird Feeders for north american bird species. www.birdhouses101.com/ - [Cached](#) - [Similar](#) - [🔄](#)
- Bird Feeders, Bird Houses - The Backyard Bird Company** - Bird Feeders - The Backyard Bird Company has a variety of bird feeders will accent your landscape and attract wildlife. www.backyardbird.com/ - [Cached](#) - [Similar](#) - [🔄](#)

- ▶ *Web advertising*
- ▶ *Product recommendation*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems

The image shows a Google search results page for the query "bird houses". The search bar at the top contains "bird houses" and the search button is labeled "Search". To the right of the search bar are links for "Advanced Search" and "Preferences". Below the search bar, the text "Results 1 - 10 of about 22,100,000 for bird houses (0.19)" is displayed. Two red arrows point to the "Sponsored Links" section, which is highlighted in yellow. The sponsored links include:

- Bird Houses** (www.Scotts.com) - Scotts attracts colorful birds to your backyard!
- Specialty Bird Houses** (www.birds-out-back.com) - Roosting Boxes, Purple Martins, Bat Chalets.
- Bird Houses at BestNest** (www.bestnest.com) - Over 225 different houses in stock. Free shipping!
- Learn More About Bird Houses** (JustBirdHouses.net) - learn more about blue bird houses and birdhouses, along with our blue bird house and purple martin bird houses.
- Bird Houses** (www.birdhouses101.com) - Bird Feeders and Bird Feeders for north american bird species.
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- Bird Houses - Birdfeeders - Decorative Bird Houses** (www.backyardbird.com) - Cached - Similar -

On the right side of the page, there is a "Sponsored Links" section with the following items:

- Bird Houses** - Find All Types Of Bird Feeders And Houses At Low Prices! New Lower Prices! www.Lowes.com
- Bird Houses Sale** - Authorized Dealer - New Designs. Low Price Guarantee- Free Shipping www.OutdoorLivingShowroom.com
- High Quality Bird Houses** - Nesting boxes & decorative houses. 5-Star Service. Free Shipping \$75+ www.backyardbird.com
- Decorative Bird Houses** - Beautify Your Garden With Our Wooden Bird Houses at a Discount. BirdHouseStation.com

- ▶ *Web advertising*
- ▶ *Product recommendation*
- ▶ *Date matching*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems
- ▶ Social applications



Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems
- ▶ Social applications



- ▶ *Bike sharing optimization*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems
- ▶ Social applications



- ▶ *Bike sharing optimization*
- ▶ *Election campaign*

Why: Important Problems

- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems
- ▶ Social applications



- ▶ *Bike sharing optimization*
- ▶ *Election campaign*
- ▶ *ER service optimization*

Why: Important Problems

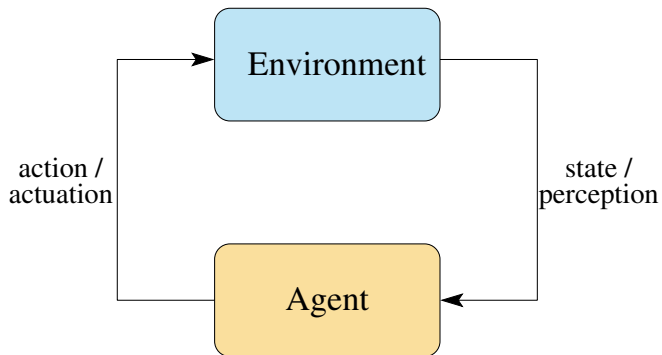
- ▶ Autonomous robotics
- ▶ Financial applications
- ▶ Energy management
- ▶ Recommender systems
- ▶ Social applications



- ▶ *Bike sharing optimization*
- ▶ *Election campaign*
- ▶ *ER service optimization*
- ▶ *Intelligent Tutoring Systems*

What

What: Decision-Making under Uncertainty



How: 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**).

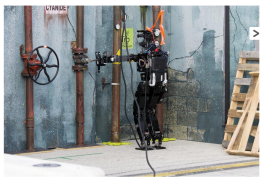
*“An introduction to reinforcement learning”,
Sutton and Barto (1998).*

How: the Course

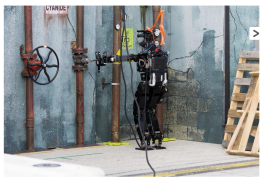
How: the Course



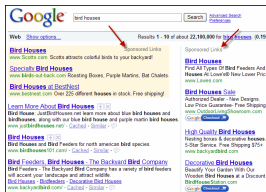
How: the Course



How: the Course



How: the Course



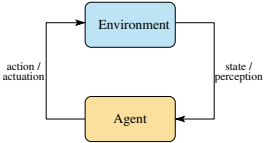
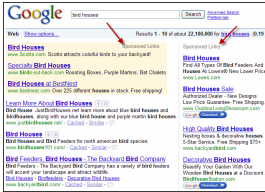
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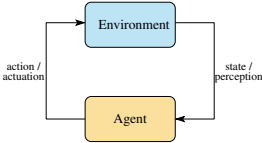
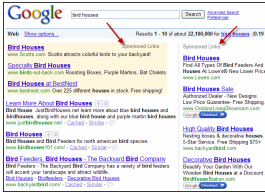
Google search results for "bird houses". The search bar shows "bird houses" and the search button is labeled "Advanced Search". The results show 1-19 of about 22,190,800 for bird houses (0.15). The results include several links to websites selling bird houses, such as "Bird Houses - Scotts care", "Specialty Bird Houses", "Bird Houses at Bechtel", "Learn More About Bird Houses", "Bird Houses - The Backyard Bird Company", "Bird Feeders, Bird Houses - The Backyard Bird Company", "Bird Houses - Backfeeders", "Bird Houses", "Bird Houses Sale", "High Quality Bird Houses", and "Decorative Bird Houses".



How: the Course



How: the Course



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



What: the Highlights of the Course

How to *model* an RL problem

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

What: the Highlights of the Course

How to *model* an RL problem

How to solve *exactly* an RL problem

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

What: the Highlights of 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

What: the Highlights of 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

What: the Highlights of 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 dynamic programming
- ▶ *Tools*: statistical learning theory

What: the Highlights of 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 examples from *resource optimization*, *trade execution*,
(computer) *games*, *recommendation systems*.

When/What/Where

- ▶ 7 lectures
- ▶ 4 practical sessions (and homework) [*1 point each*]
- ▶ 1 final project (report and oral presentation) [*16 points*]

Opportunities for *spring internship* and *Ph.D.* positions.

When/What/Where

researchers.lille.inria.fr/~lazarcic/Webpage/Teaching.html

<i>Date</i>	<i>Topic</i>	<i>Classroom</i>
29/09	Intro/MDP	Conference
06/10	Dynamic Programming	Condorcet
13/10	RL Algorithms	Condorcet
20/10	<i>TP</i> on DP and RL	Condorcet
27/10	Multi-arm Bandit (1)	Condorcet
03/11	<i>TP</i> on Bandit	Amphi Curie
10/11	Multi-arm Bandit (2) [projects]	Amphi Curie
17/11	<i>TP</i> on Bandit	Condorcet
24/11	Approximate DP	Condorcet
01/12	<i>TP</i> on ADP	Condorcet
08/12	Sample Complexity of ADP	Condorcet
15/12	Guest lecture	(TBD)
mid-Jan	Evaluation	(TBD)

Lectures are from 11am to 1pm, TP from 11am to 1:15pm.

Reinforcement Learning

The Inria logo is displayed in a red, cursive font within a white rounded square, which is set against a teal background.

Inria

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