BE a reinforcement learner
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- You, as a class, act as a learning agent
BE a reinforcement learner

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- **Actions**: Wave, Stand, Clap
BE a reinforcement learner

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- **Observations**: colors, reward
BE a reinforcement learner

- You, as a class, act as a learning agent
- **Actions**: Wave, Stand, Clap
- **Observations**: colors, reward
- **Goal**: Find an optimal *policy*
BE a reinforcement learner

- You, as a class, act as a learning agent
- **Actions**: Wave, Stand, Clap
- **Observations**: colors, reward
- **Goal**: Find an optimal *policy*
  - Way of selecting actions that gets you the most reward
How did you do it?
How did you do it?

• What is your policy?

• What does the world look like?
How did you do it?

- What is your policy?
- What does the world look like?
Formalizing What Just Happened

Knowns:
Formalizing What Just Happened

Knowns:

- $\mathcal{O} = \{\text{Blue, Red, Green, Black, \ldots}\}$
- Rewards in $\mathbb{R}$
- $A = \{\text{Wave, Clap, Stand}\}$
Formalizing What Just Happened

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- $\mathcal{O} = \{\text{Blue, Red, Green, Black, \ldots}\}$
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- $\mathcal{A} = \{\text{Wave, Clap, Stand}\}$

$$o_0, a_0, r_0, o_1, a_1, r_1, o_2, \ldots$$
Formalizing What Just Happened

Knowns:
- $O = \{\text{Blue}, \text{Red}, \text{Green}, \text{Black}, \ldots\}$
- Rewards in $\mathbb{R}$
- $A = \{\text{Wave, Clap, Stand}\}$

Unknowns:

- $o_0, a_0, r_0, o_1, a_1, r_1, o_2, \ldots$
Formalizing What Just Happened

Knowns:
- \( \mathcal{O} = \{\text{Blue, Red, Green, Black, \ldots}\} \)
- Rewards in \( \mathbb{R} \)
- \( \mathcal{A} = \{\text{Wave, Clap, Stand}\} \)
- \( o_0, a_0, r_0, o_1, a_1, r_1, o_2, \ldots \)

Unknowns:
- \( S = 4 \times 3 \) grid
- \( \mathcal{R} : S \times \mathcal{A} \mapsto \mathbb{R} \)
- \( \mathcal{T} : S \mapsto \mathcal{O} \)
- \( \mathcal{P} : S \times \mathcal{A} \mapsto S \)
Formalizing What Just Happened

Knowns:

- $\mathcal{O} = \{\text{Blue, Red, Green, Black, ...}\}$
- Rewards in $\mathbb{R}$
- $\mathcal{A} = \{\text{Wave, Clap, Stand}\}$

$$o_0, a_0, r_0, o_1, a_1, r_1, o_2, \ldots$$

Unknowns:

- $S =$ 4x3 grid
- $\mathcal{R} : S \times \mathcal{A} \rightarrow \mathbb{R}$
- $T = S \rightarrow \mathcal{O}$
- $\mathcal{P} : S \times \mathcal{A} \rightarrow S$

$$s_0, o_0, a_0, r_0, s_1, o_1, a_1, r_1, s_2, o_2, \ldots$$
Formalizing What Just Happened

Knowns:
- $\mathcal{O} = \{\text{Blue, Red, Green, Black, } \ldots\}$
- Rewards in $\mathbb{R}$
- $\mathcal{A} = \{\text{Wave, Clap, Stand}\}$

Unknows:
- $\mathcal{S} =$ 4x3 grid
- $\mathcal{R} : \mathcal{S} \times \mathcal{A} \mapsto \mathbb{R}$
- $\mathcal{T} = \mathcal{S} \mapsto \mathcal{O}$
- $\mathcal{P} : \mathcal{S} \times \mathcal{A} \mapsto \mathcal{S}$

$o_i = \mathcal{T}(s_i)$
Formalizing What Just Happened

Knowns:
- \( \mathcal{O} = \{ \text{Blue, Red, Green, Black, \ldots} \} \)
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Unknowns:
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- \( \mathcal{R} : S \times \mathcal{A} \rightarrow \mathbb{R} \)
- \( \mathcal{T} = S \rightarrow \mathcal{O} \)
- \( \mathcal{P} : S \times \mathcal{A} \rightarrow S \)

\[
\begin{align*}
o_0, a_0, r_0, o_1, a_1, r_1, o_2, \ldots \\
s_0, o_0, a_0, r_0, s_1, o_1, a_1, r_1, s_2, o_2, \ldots \\
o_i = \mathcal{T}(s_i) \\
r_i = \mathcal{R}(s_i, a_i)
\end{align*}
\]
Formalizing What Just Happened

Knowns:

- $\mathcal{O} = \{\text{Blue, Red, Green, Black, …}\}$
- Rewards in $\mathbb{R}$
- $\mathcal{A} = \{\text{Wave, Clap, Stand}\}$

Unknowns:

- $\mathcal{S} = 4\times3$ grid
- $\mathcal{R} : \mathcal{S} \times \mathcal{A} \mapsto \mathbb{R}$
- $\mathcal{T} = \mathcal{S} \mapsto \mathcal{O}$
- $\mathcal{P} : \mathcal{S} \times \mathcal{A} \mapsto \mathcal{S}$

$$o_i = \mathcal{T}(s_i) \quad r_i = \mathcal{R}(s_i, a_i) \quad s_{i+1} = \mathcal{P}(s_i, a_i)$$
This Course

- Reinforcement Learning theory (start)
This Course

- Reinforcement Learning theory (start)
- Reinforcement Learning in practice (end)
The Big Picture

- AI
The Big Picture

- AI → ML
The Big Picture

- AI → ML → RL
The Big Picture

- AI $\rightarrow$ ML $\rightarrow$ RL

- Types of Machine Learning
The Big Picture

- AI $\rightarrow$ ML $\rightarrow$ RL

- Types of Machine Learning
  
  **Supervised learning:** learn from labeled examples
The Big Picture

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  **Supervised learning:** learn from labeled examples
  **Unsupervised learning:** cluster unlabeled examples
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  **Supervised learning:** learn from labeled examples
  **Unsupervised learning:** cluster unlabeled examples
  **Reinforcement learning:** learn from interaction
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- Types of Machine Learning

  **Supervised learning:** learn from labeled examples
  **Unsupervised learning:** cluster unlabeled examples
  **Reinforcement learning:** learn from interaction
    - Defined by the problem
The Big Picture

• AI $\rightarrow$ ML $\rightarrow$ RL

• Types of Machine Learning
  
  **Supervised learning:** learn from labeled examples
  
  **Unsupervised learning:** cluster unlabeled examples
  
  **Reinforcement learning:** learn from interaction
    
    – Defined by the problem
    
    – Many approaches possible (including evolutionary)
The Big Picture

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- Types of Machine Learning

  **Supervised learning:** learn from labeled examples
  **Unsupervised learning:** cluster unlabeled examples
  **Reinforcement learning:** learn from interaction
  - Defined by the problem
  - Many approaches possible (including evolutionary)
  - Book focusses on a particular class of approaches
Reduced Formalism

Knowns:

- \( S = \{\text{Blue, Red, Green, Black, \ldots}\} \)
- Rewards in \( \mathbb{R} \)
- \( A = \{\text{Wave, Clap, Stand}\} \)

\[ s_0, a_0, r_0, s_1, a_1, r_1, s_2, \ldots \]
Reduced Formalism

**Knowns:**
- \( S = \{\text{Blue, Red, Green, Black, \ldots}\} \)
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\[ s_0, a_0, r_0, s_1, a_1, r_1, s_2, \ldots \]

**Unknowns:**
Reduced Formalism

Knowns:

1. \( S = \{\text{Blue, Red, Green, Black,} \ldots \} \)
2. Rewards in \( \mathbb{R} \)
3. \( A = \{\text{Wave, Clap, Stand}\} \)

\[
\begin{array}{c}
S_0, a_0, r_0, s_1, a_1, r_1, s_2, \ldots \\
\end{array}
\]

Unknowns:

1. \( R : S \times A \mapsto \mathbb{R} \)
2. \( P : S \times A \mapsto S \)
Reduced Formalism

Knowns:

- \( S = \{\text{Blue, Red, Green, Black, ...}\} \)
- Rewards in \( R \)
- \( A = \{\text{Wave, Clap, Stand}\} \)

\[
s_0, a_0, r_0, s_1, a_1, r_1, s_2, \ldots
\]

Unknowns:

- \( \mathcal{R} : S \times A \mapsto \mathbb{R} \)
- \( \mathcal{P} : S \times A \mapsto S \)

\[
r_i = \mathcal{R}(s_i, a_i) \quad \quad s_{i+1} = \mathcal{P}(s_i, a_i)
\]
This course

- Agent’s perspective: only policy under control
  - State representation, reward function given
  - Focus on policy algorithms, theoretical analyses
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  - Appeal: program by just specifying goals
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• Methodical approach
  – Solid foundation rather than comprehensive coverage
This course

- Agent’s perspective: only **policy** under control
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  - Focus on policy algorithms, theoretical analyses
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- Methodical approach
  - Solid foundation rather than comprehensive coverage
  - RL reading group
Syllabus

- Available on-line
Assignments

- Join piazza!
Assignments

• Join piazza!

• Read Chapter 2 (and 1 if you haven’t)
Assignments

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- Send a reading response by 5pm Monday
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Assignments

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• Need discussion leader volunteers and experiment presenters