Reward shaping

Reward shaping

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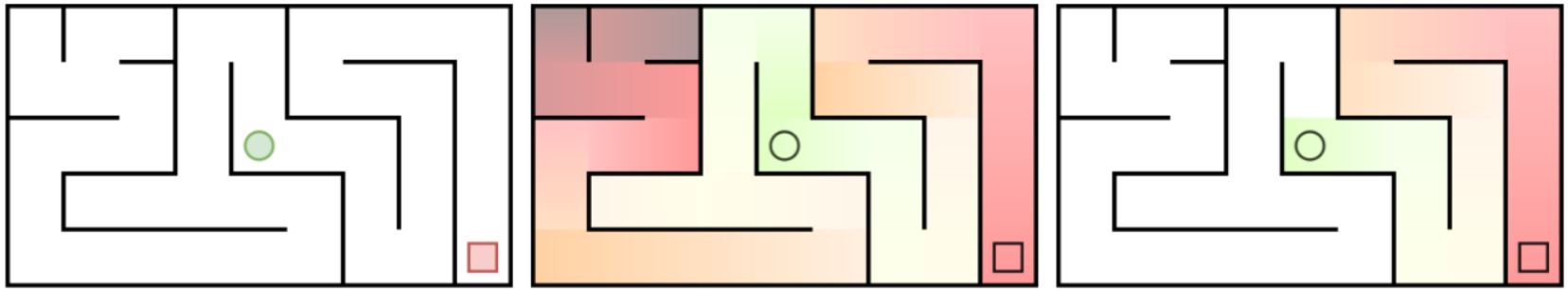
Reward shaping

- covers all methods that modify the reward given to the agent in order to optimize (speed up) training
- incorporates prior knowledge about the task into the reward function

Example: Different levels of reward shaping depending on the distance to the goal



https://arxiv.org/pdf/2210.09579.pdf

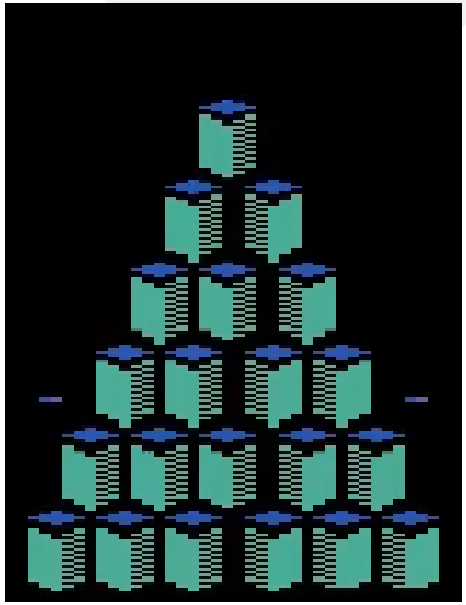
Reward shaping

Problem with RL in general

- RL is extremely good in finding bugs/loopholes in your program, this effect may get aggravated through reward shaping

Example 1: Q-Bert

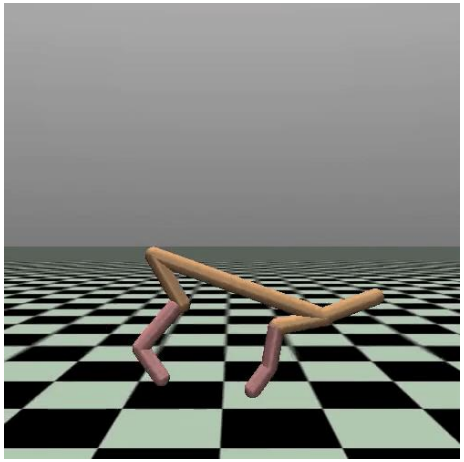
- Old Amiga game, RL agent found a (previously unknown) bug during training

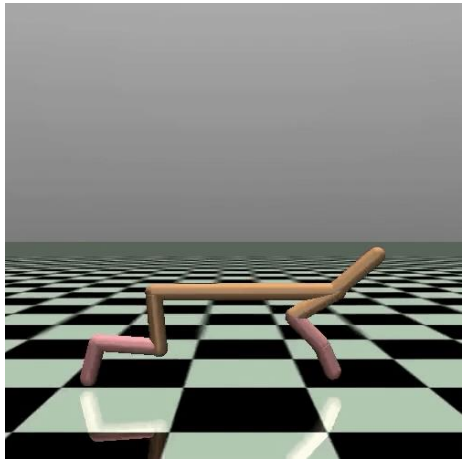


https://www.youtube.com/shorts/uVHAAIA3F_U

Example 2: Half Cheetah

- Through optimized parameters and a more positive reward if the agent moves faster to the roll, it learned that it is faster to roll instead of running





https://bair.berkeley.edu/blog/2021/04/19/mbrl/

Reward shaping

Problem with reward shaping: Cobra effect

- Modifying a (initially simple) reward function in order to speed up training may lead to undesired consequences

Example: CoastRunners

- Real goal: Finish the race as quickly as possible
- Reward assigned to agent: Collect as many targets along the way

https://www.youtube.com/watch?v=tlOIHko8ySg&t=5s

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Types of rewards

immediate rewards get reward immediately after taking an action	vs.	**delayed rewards** get reward some time after taking an action
dense rewards get reward every timestep	vs.	**sparse rewards** do not get reward every timestep
positive rewards rewards $R_t \geq 0$	vs.	**negative rewards** rewards $R_t \leq 0$
individual rewards focus on one task aspect	vs.	**additive rewards** focus on many task aspects

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Immediate vs. delayed rewards

Immediate rewards

- Get a reward (associated with that action) immediately after taking the action
- Examples
  - Autonomous driving: Distance to target
  - Learning to walk: Distance traveled

Delayed rewards

- Get a reward (associated with that action) some time after taking the action
- Examples
  - Games (get a reward of e.g. +1/-1 when winning/losing the game)
  - Stock market (buy stocks now, see how it performs over the years)

→ Delayed rewards are way more difficult for RL than immediate rewards, training can be sped up if suitable immediate rewards are added to delayed rewards.

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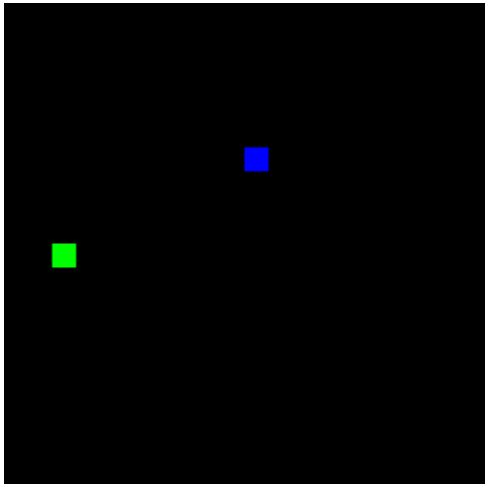
Dense vs. sparse rewards

Dense rewards

- Get a reward at every timestep
- Examples
  - Robot maze
  - Autonomous driving: Distance to target update every second



https://medium.com/ml-everything/reinforcement-learning-with-sparse-rewards-8f15b71d18bf

Sparse rewards

- Don't get a reward at every timestep (e.g. every N steps)
- Examples
  - Snake
  - Soccer: Goals scored

→ Sparse rewards are usually more difficult than dense rewards but by far not as difficult as massive delayed rewards

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Positive vs. negative rewards

Positive rewards

- Get a positive reward when taking a good action or reaching the goal state
- Examples
  - Learning to walk: Distance traveled

Negative rewards

- Get a negative reward for every action that does not reach the goal state
- Examples
  - Robot maze

→ Negative rewards encourage the agent to reach a goal state as quickly as possible, positive rewards may stimulate the robot to accumulate reward rather than reaching the goal state (useful for e.g. non-episodic tasks)

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Individual vs. additive rewards

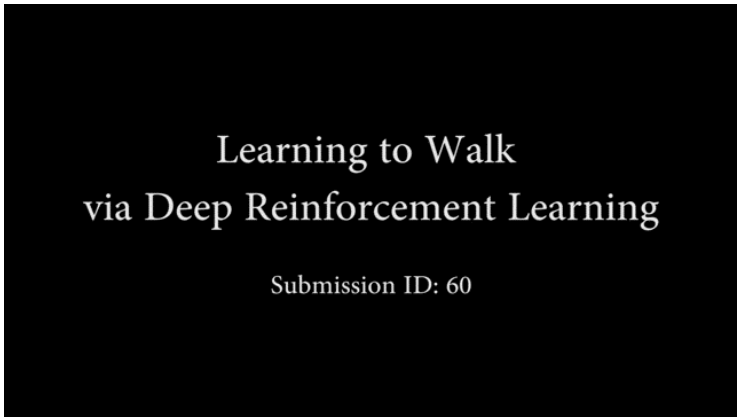
Individual rewards

- Rewards focusing only on the main aspect of the task
- Examples
  - Learning to walk: Distance travelled

Additive rewards

- Rewards focusing on multiple task aspects (with $\alpha, \beta, \ldots$ as weights): $R = \alpha R_a + \beta R_b + \cdots$
- Examples
  - Learning to walk: Distance travelled and torso height

→ Additive rewards can be a good addition to individual rewards if learning progress is slow



https://www.youtube.com/watch?v=n2gE7n11h1Y

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Task: How would you shape an reward for

- running (with a simulated human)
- driving a car
- playing chess

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Example: Robot maze