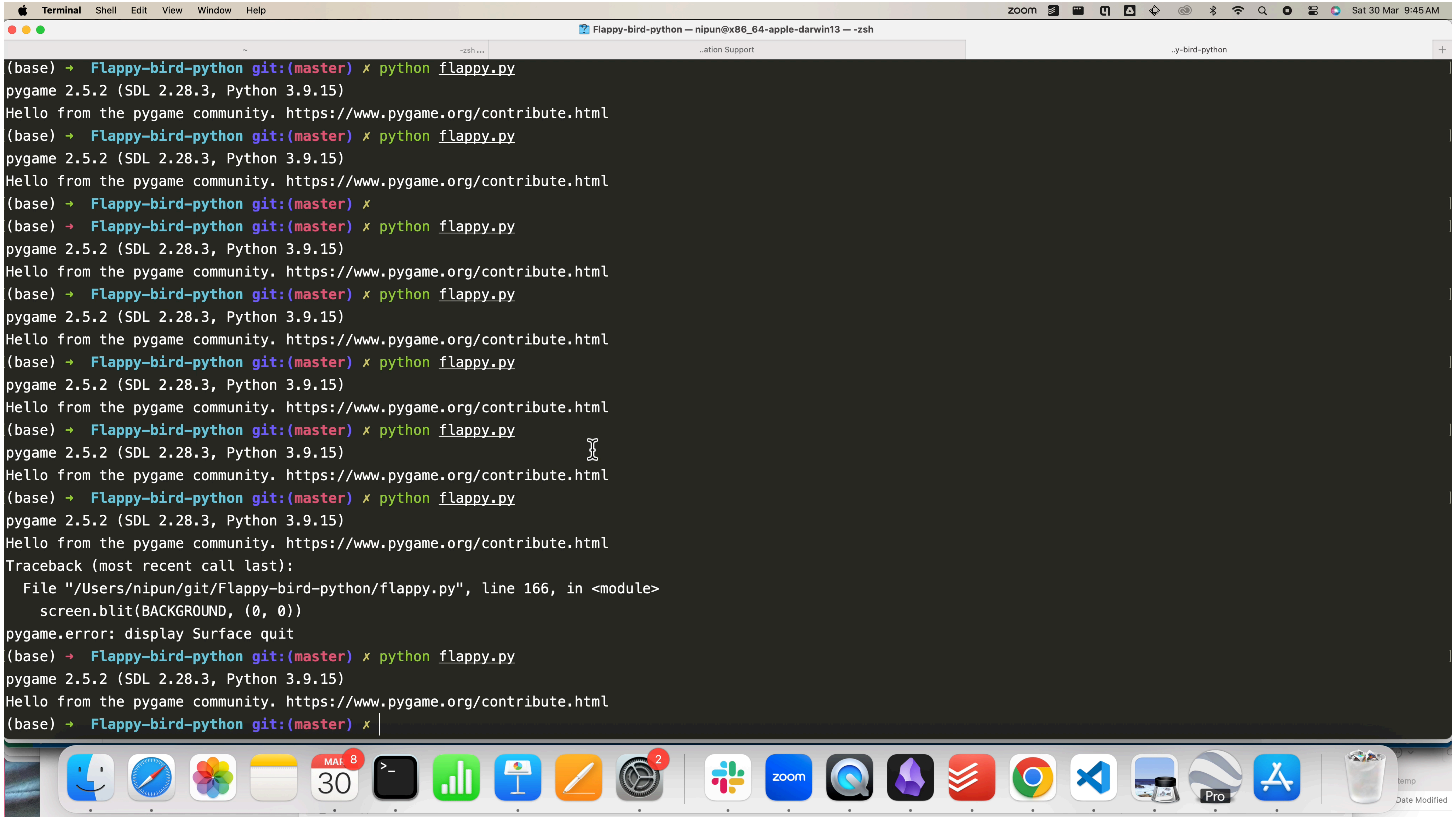
# Reinforcement Learning

Nipun Batra, 1 April 2024

# Flappy Bird


Terminal Shell Edit View Window Help
Sat 30 Mar 9:45 AM
Flappy-bird-python — nipun@x86_64-apple-darwin13 — -zsh
(base) ➜ Flappy-bird-python git:(master) ✗ python flappy.py
pygame 2.5.2 (SDL 2.28.3, Python 3.9.15)
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Traceback (most recent call last):
File "/Users/nipun/git/Flappy-bird-python/flappy.py", line 166, in <module>
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pygame.error: display Surface quit
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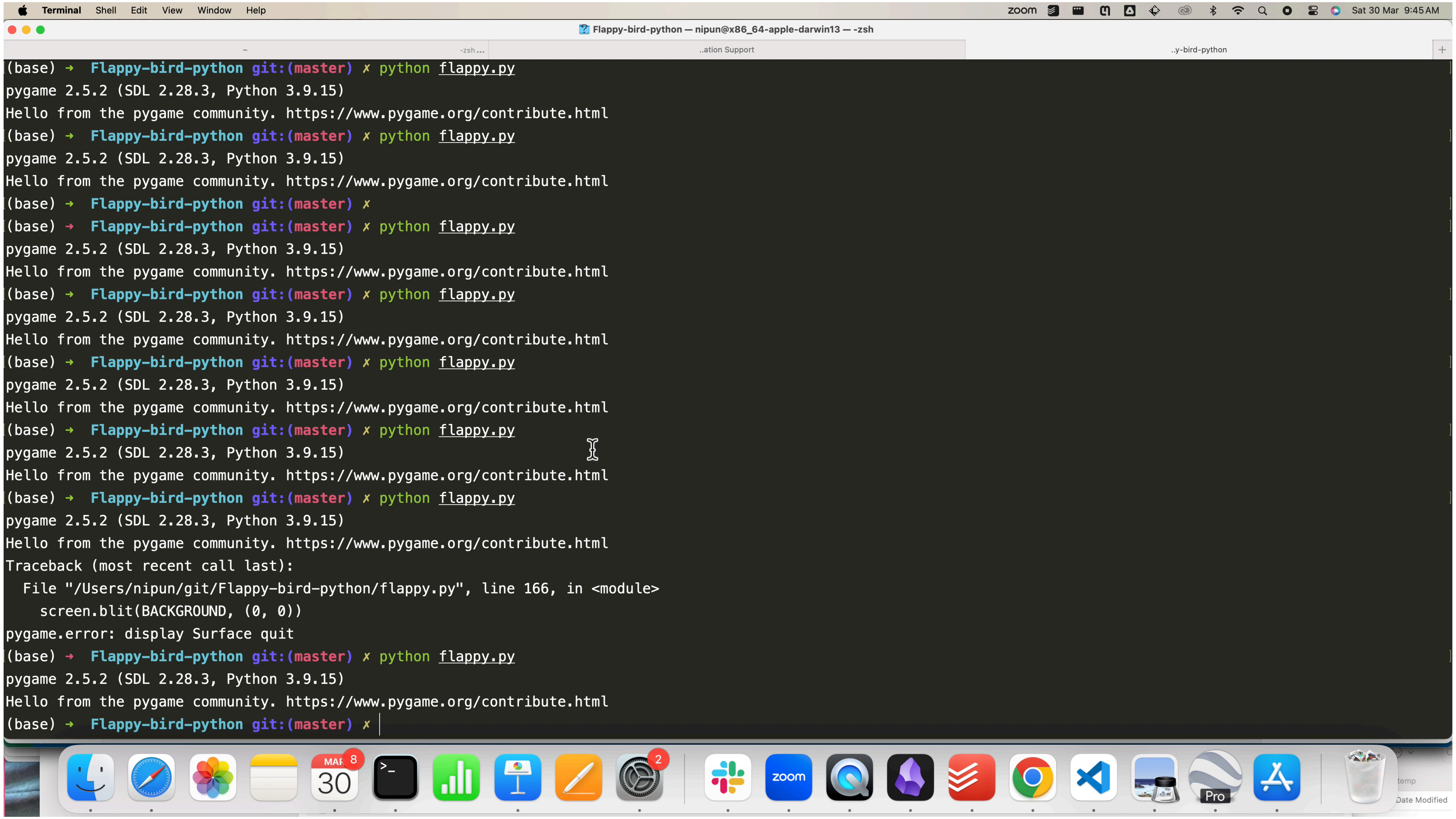
# Flappy Bird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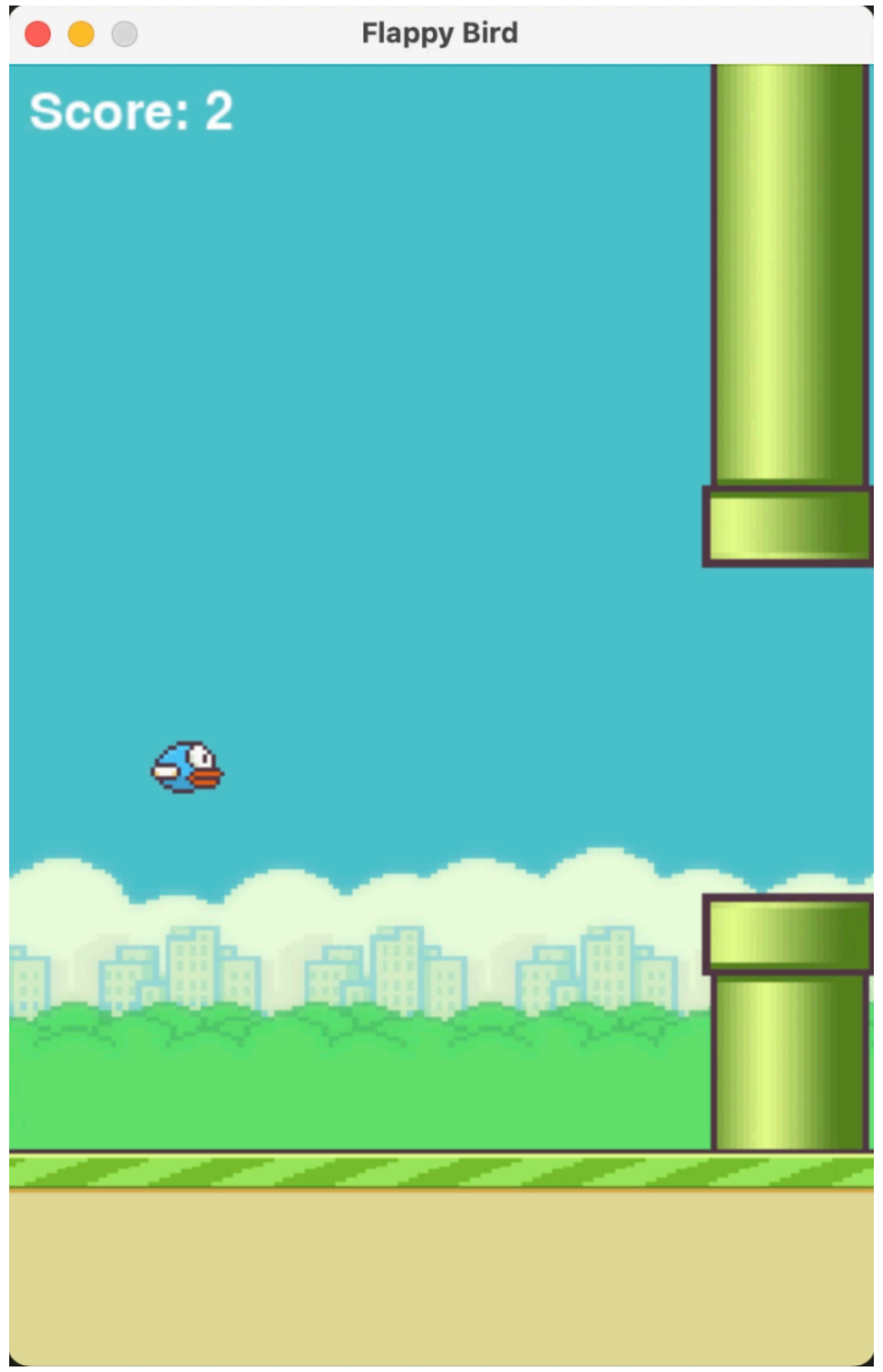
# Flappy Bird

- Game demo (Code modified from: https://github.com/LeonMarqs/Flappy-bird-python)

# Flappy Bird

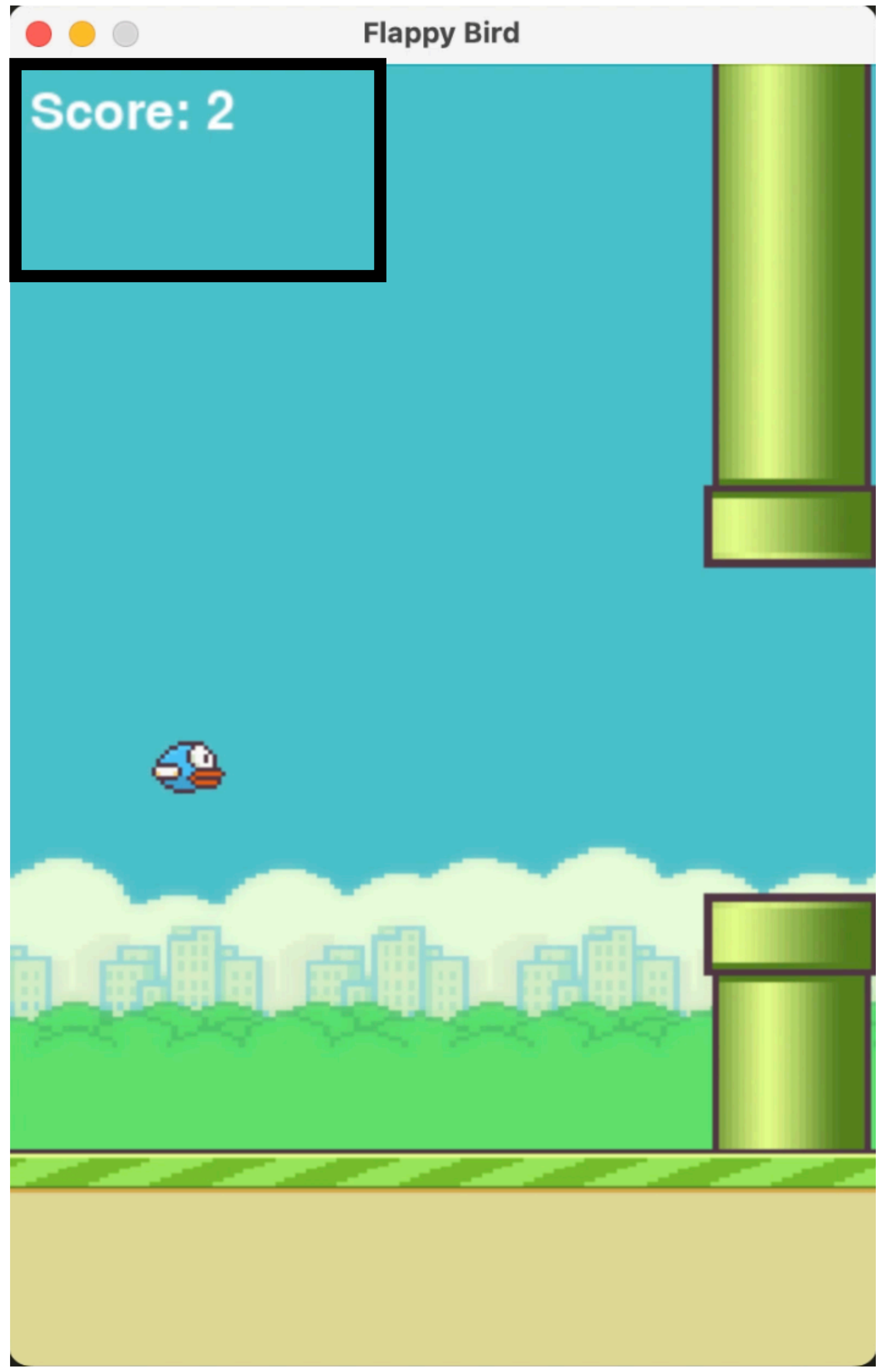
## What is the goal/objective?



# Flappy Bird

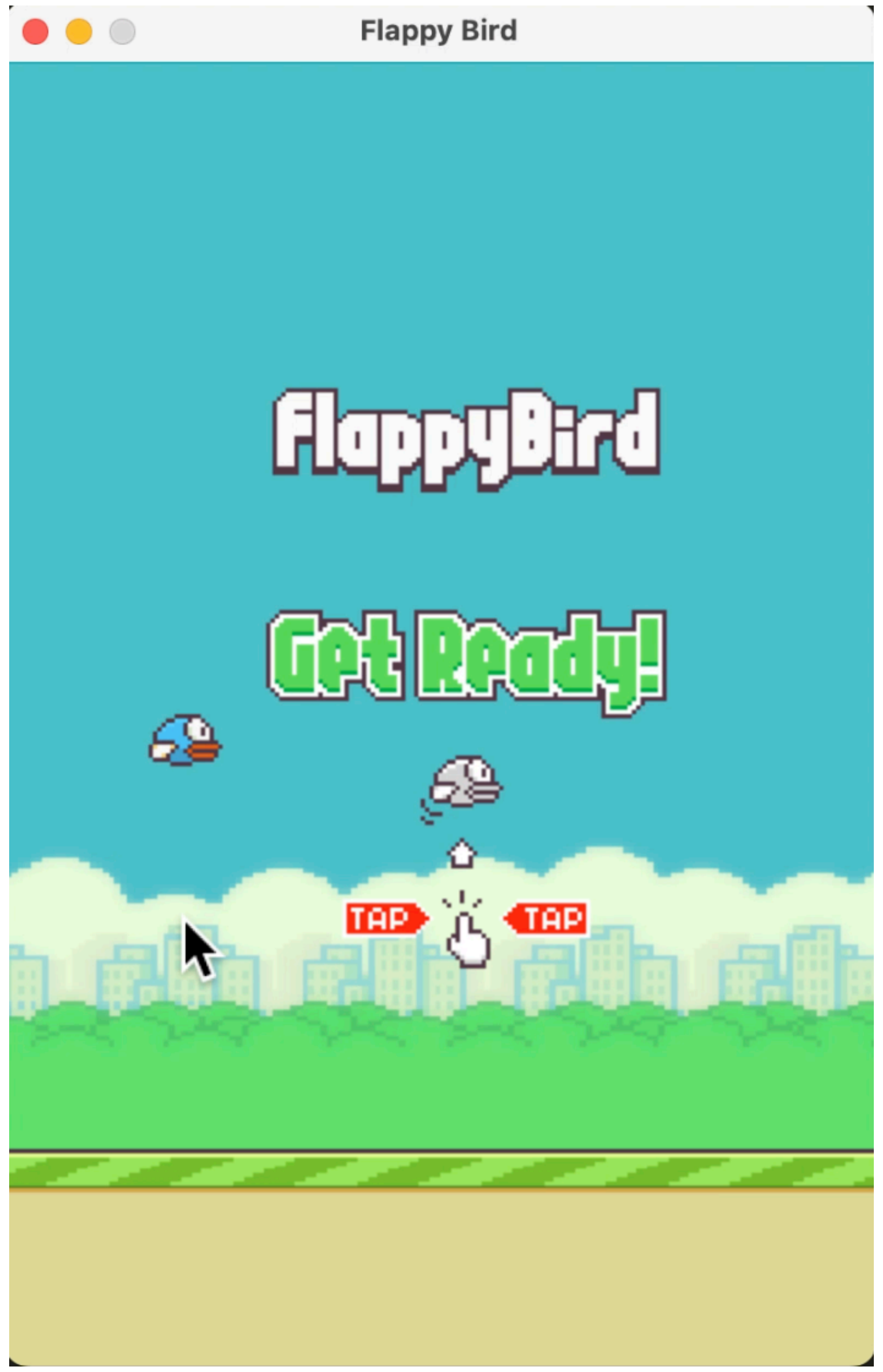
## What is the goal/objective?

- Maximise score



# Flappy Bird

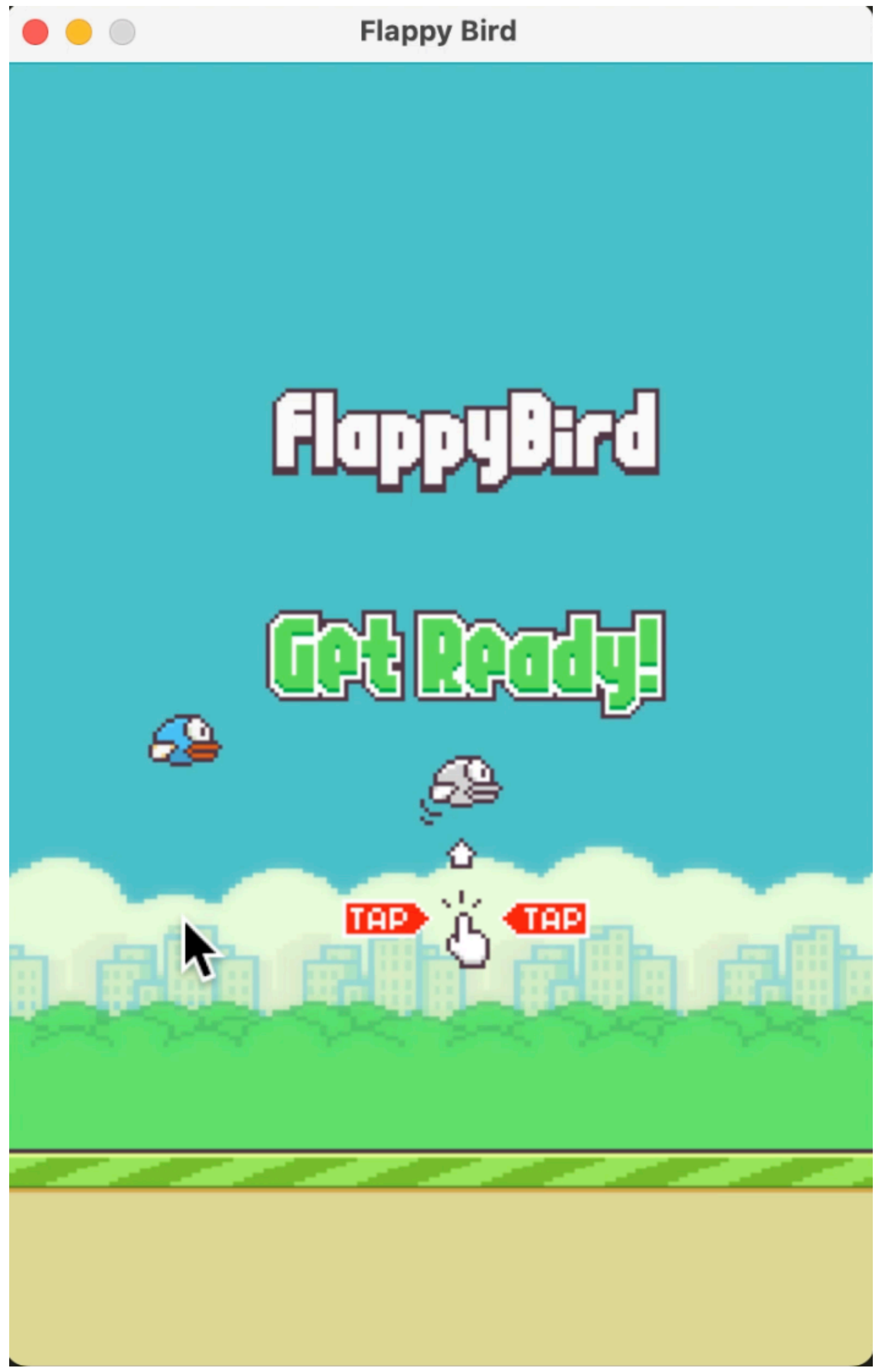
## What are the actions we can take?



# Flappy Bird

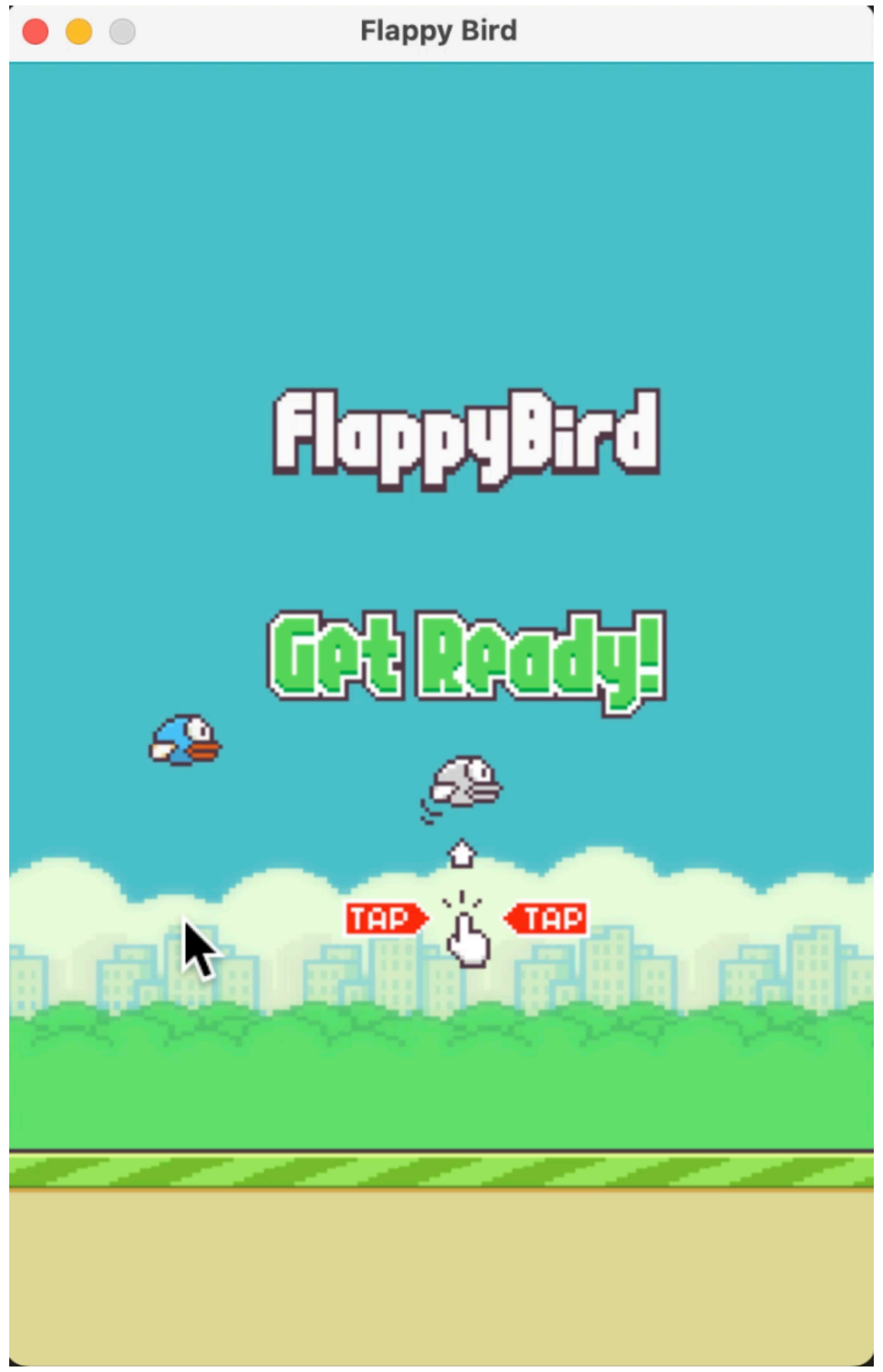
## What are the actions we can take?

- Two actions
  - Tap (Space)
  - No tap



# Flappy Bird

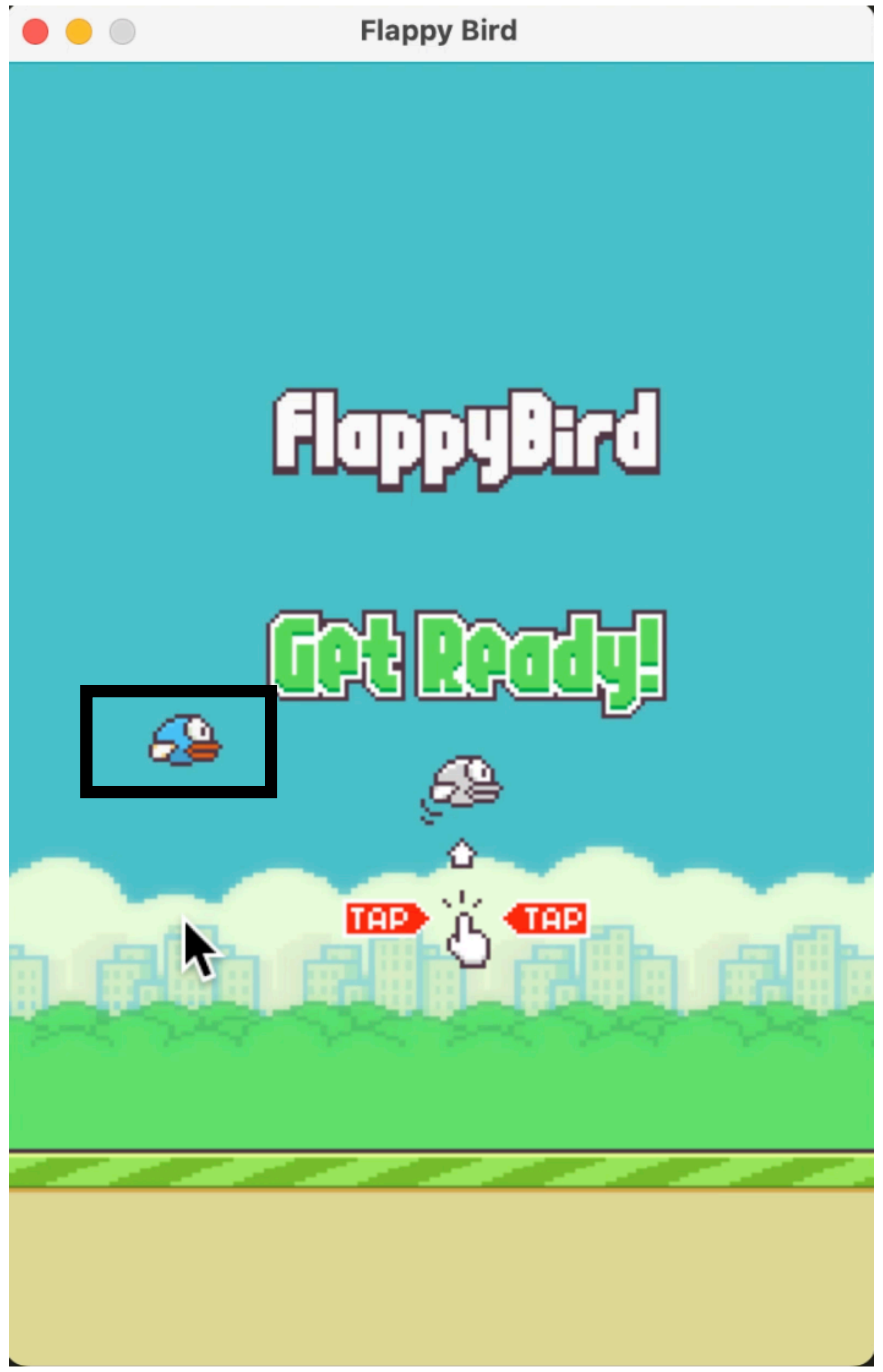
## Who is playing?



# Flappy Bird

## Who is playing?

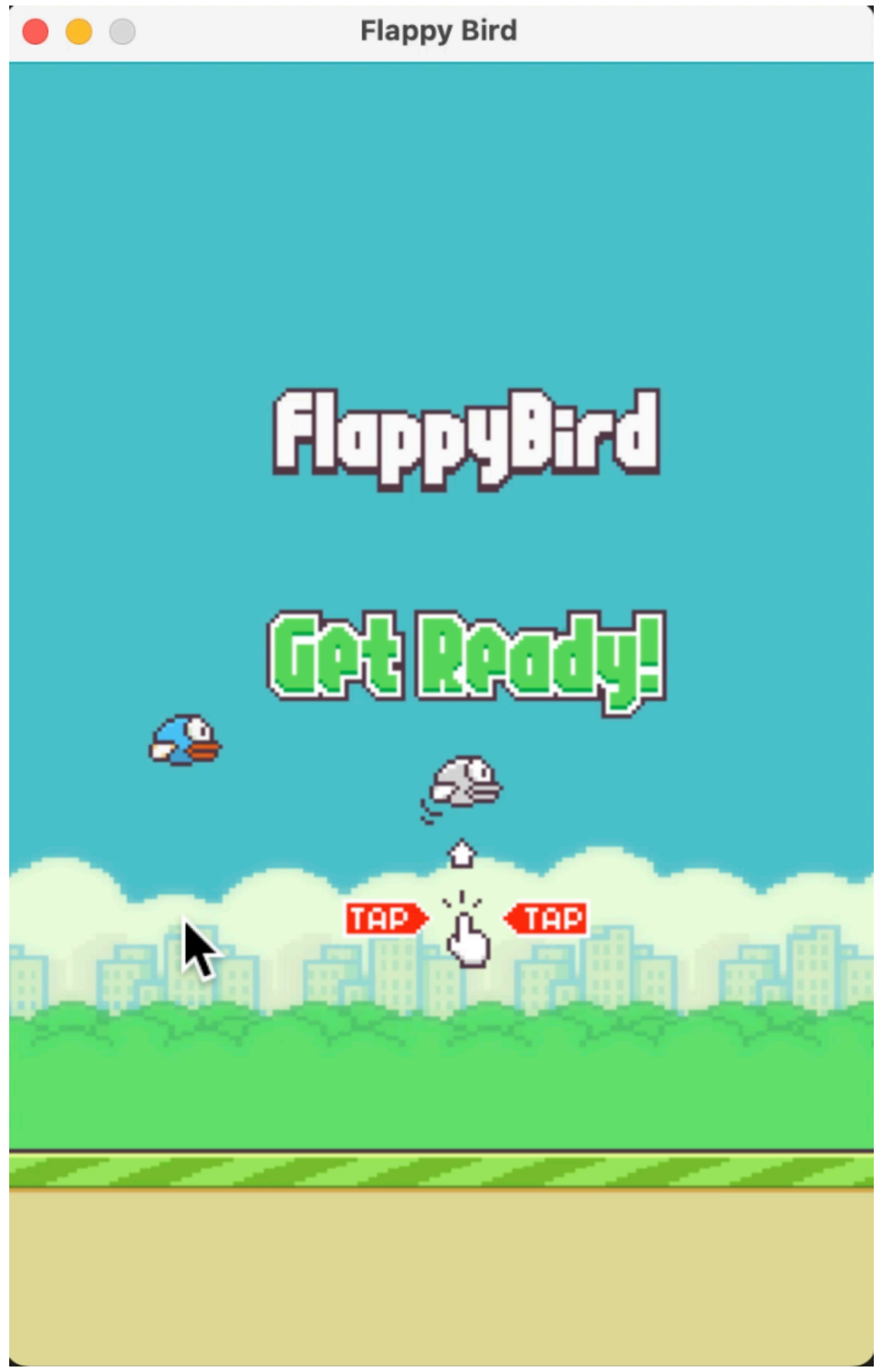
- Agent
  - You
  - Or some algorithm



# Flappy Bird

## Where are we playing?

```python
while begin:

    clock.tick(15)

    for event in pygame.event.get():
        if event.type == QUIT:
            pygame.quit()
        if event.type == KEYDOWN:
            if event.key == K_SPACE or event.key == K_UP:
                bird.bump()
                pygame.mixer.music.load(wing)
                pygame.mixer.music.play()
                begin = False

    screen.blit(BACKGROUND, (0, 0))
    screen.blit(BEGIN_IMAGE, (120, 150))

    if is_off_screen(ground_group.sprites()[0]):
        ground_group.remove(ground_group.sprites()[0])

        new_ground = Ground(GROUND_WIDHT - 20)
        ground_group.add(new_ground)

    bird.begin()
    ground_group.update()

    bird_group.draw(screen)
    ground_group.draw(screen)
```



# Flappy Bird

## Where are we playing?

- Environment
    - Code
        - generating the graphics
        - Physics rules
            - What happens when you tap
            - What happens when you hit pipe

```python
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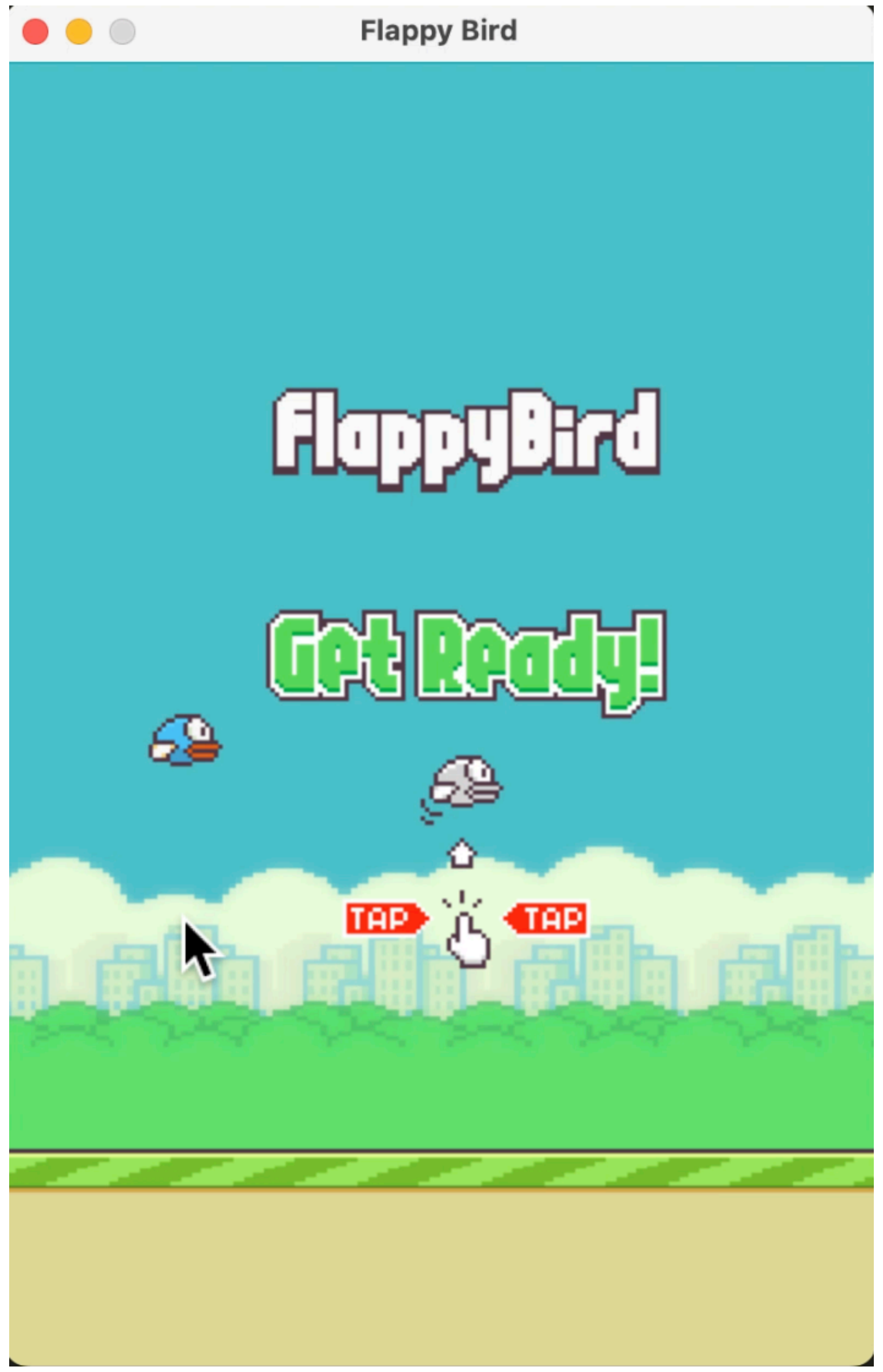


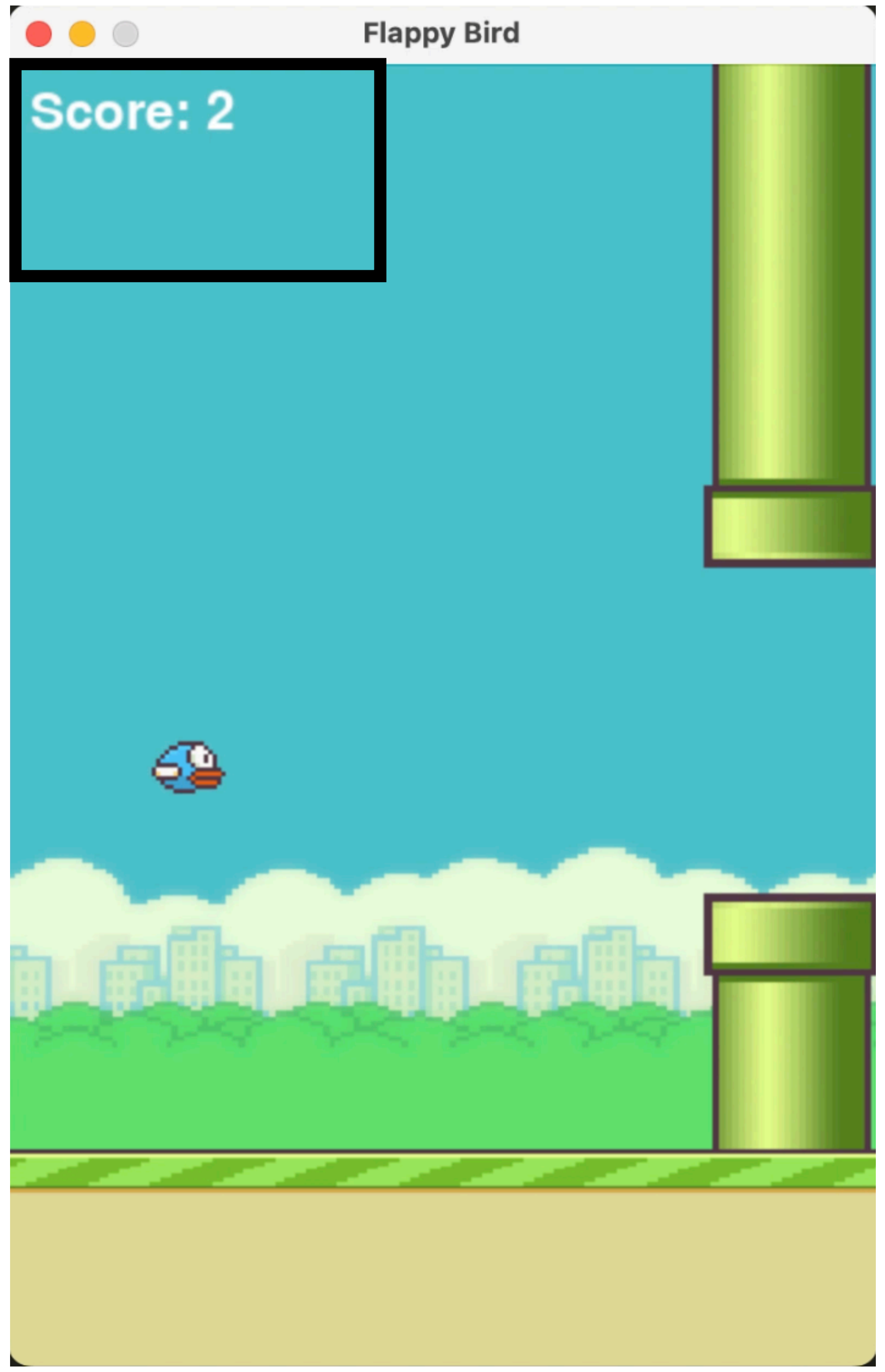
# Flappy Bird

## What does the environment provide to an agent?

# Flappy Bird

## What does the environment provide to an agent?

Reward

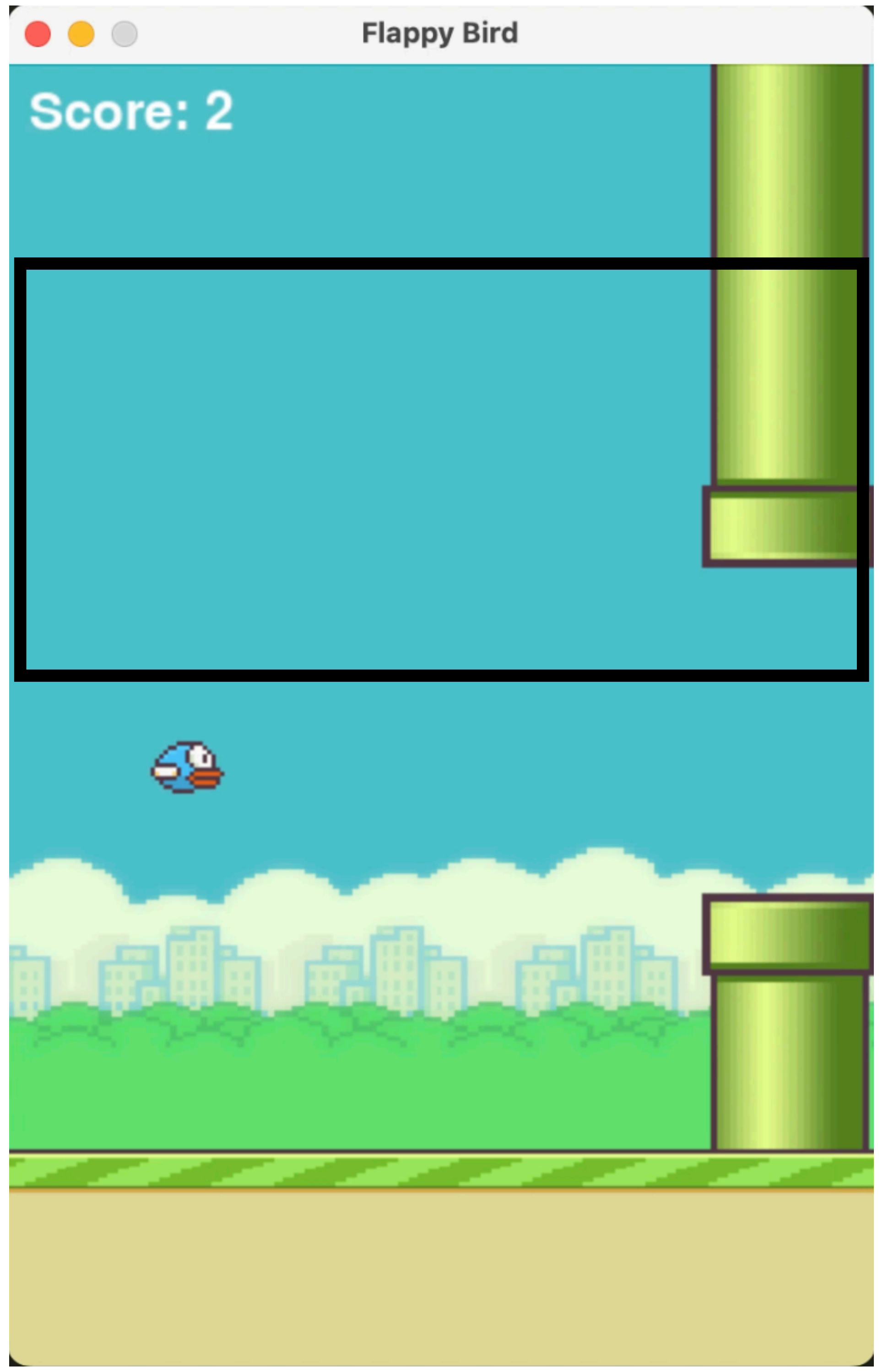


# Flappy Bird

## What does the environment provide to an agent?

**Observations**

Pixel level information

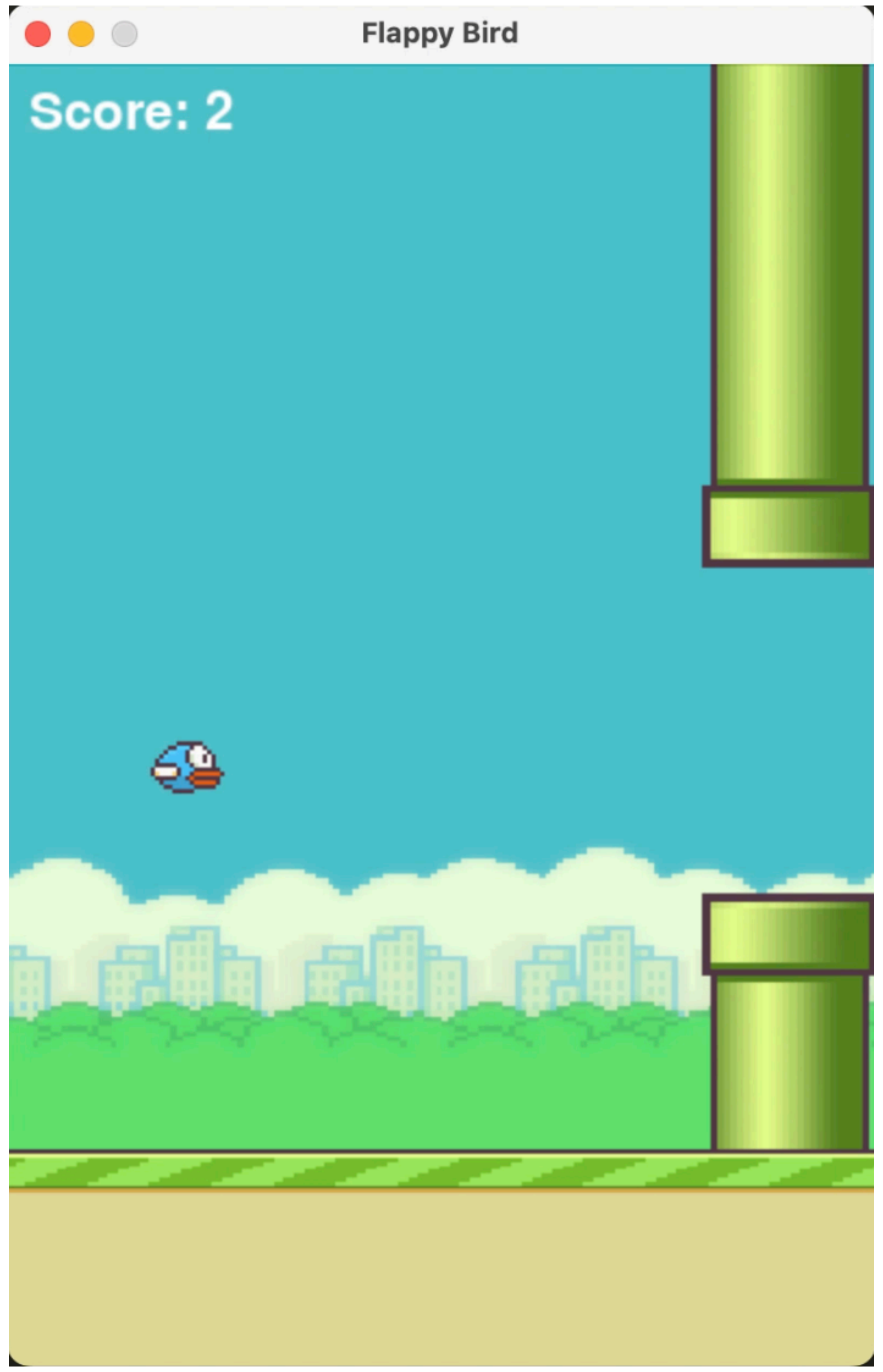


# Flappy Bird

## How does an agent decide what action to take?

**Should the agent**

**tap or not?**

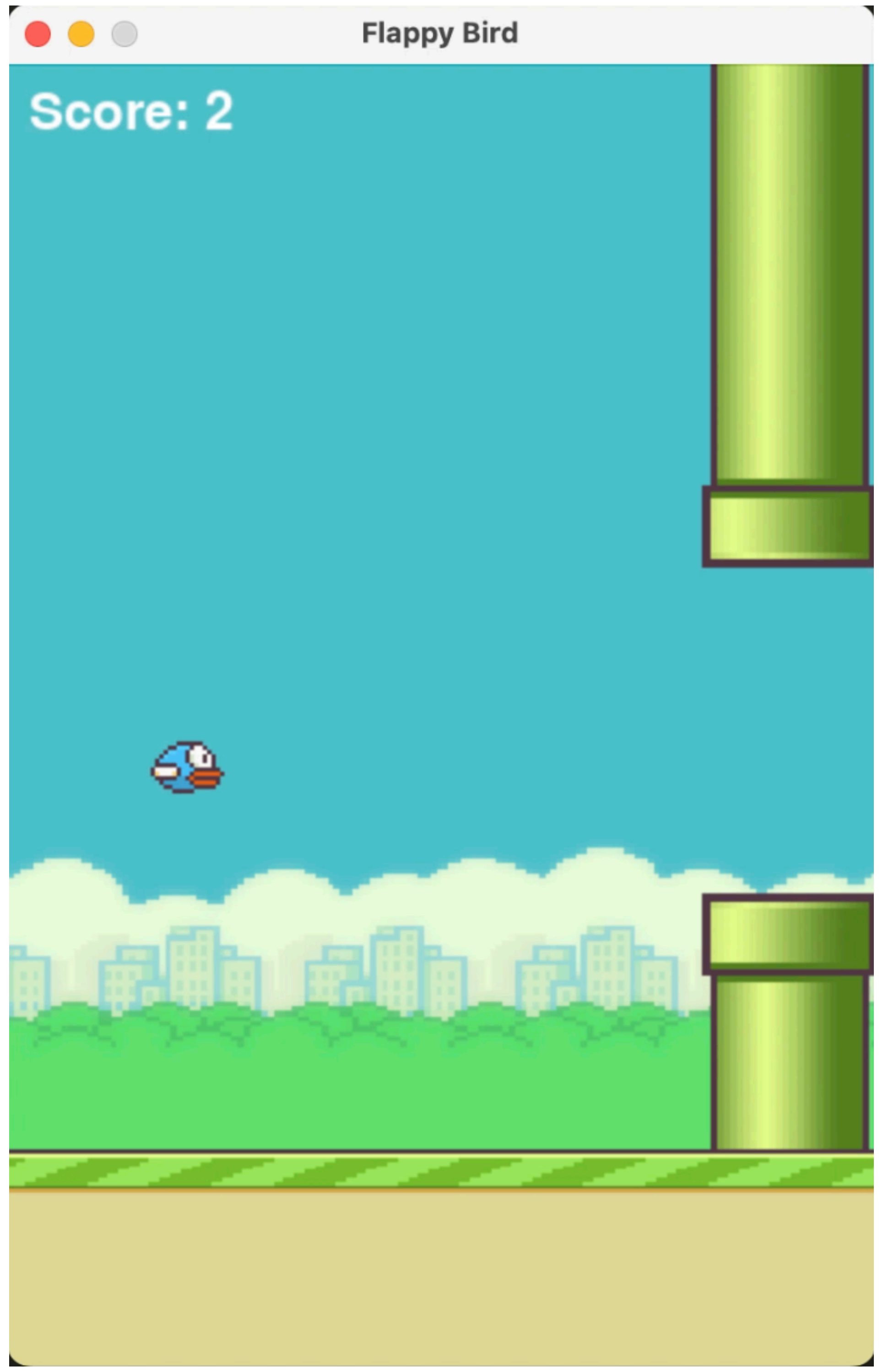


# Flappy Bird

## How does an agent decide what action to take?

**State**

Process observation into a "state"



# Flappy Bird

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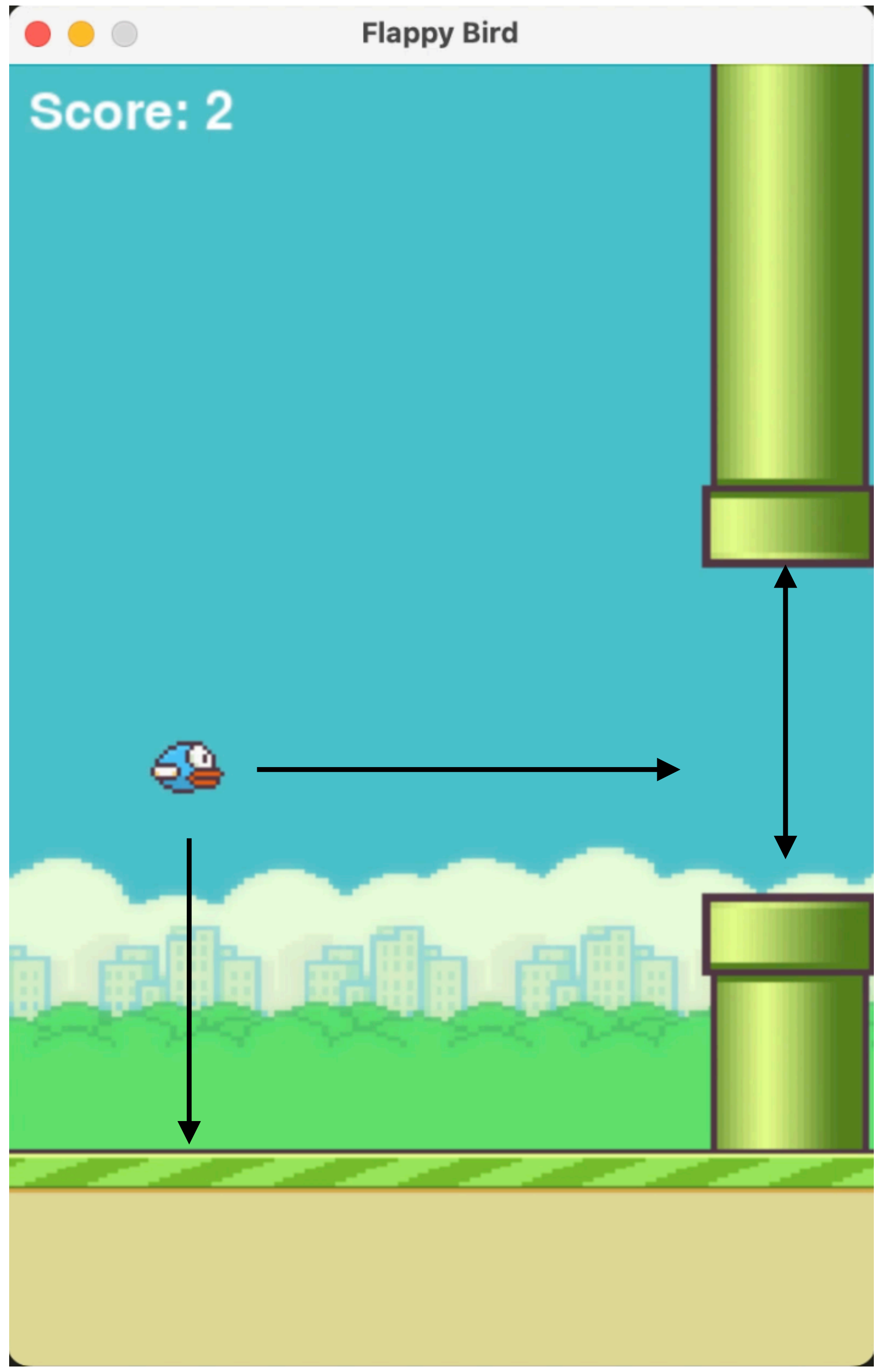
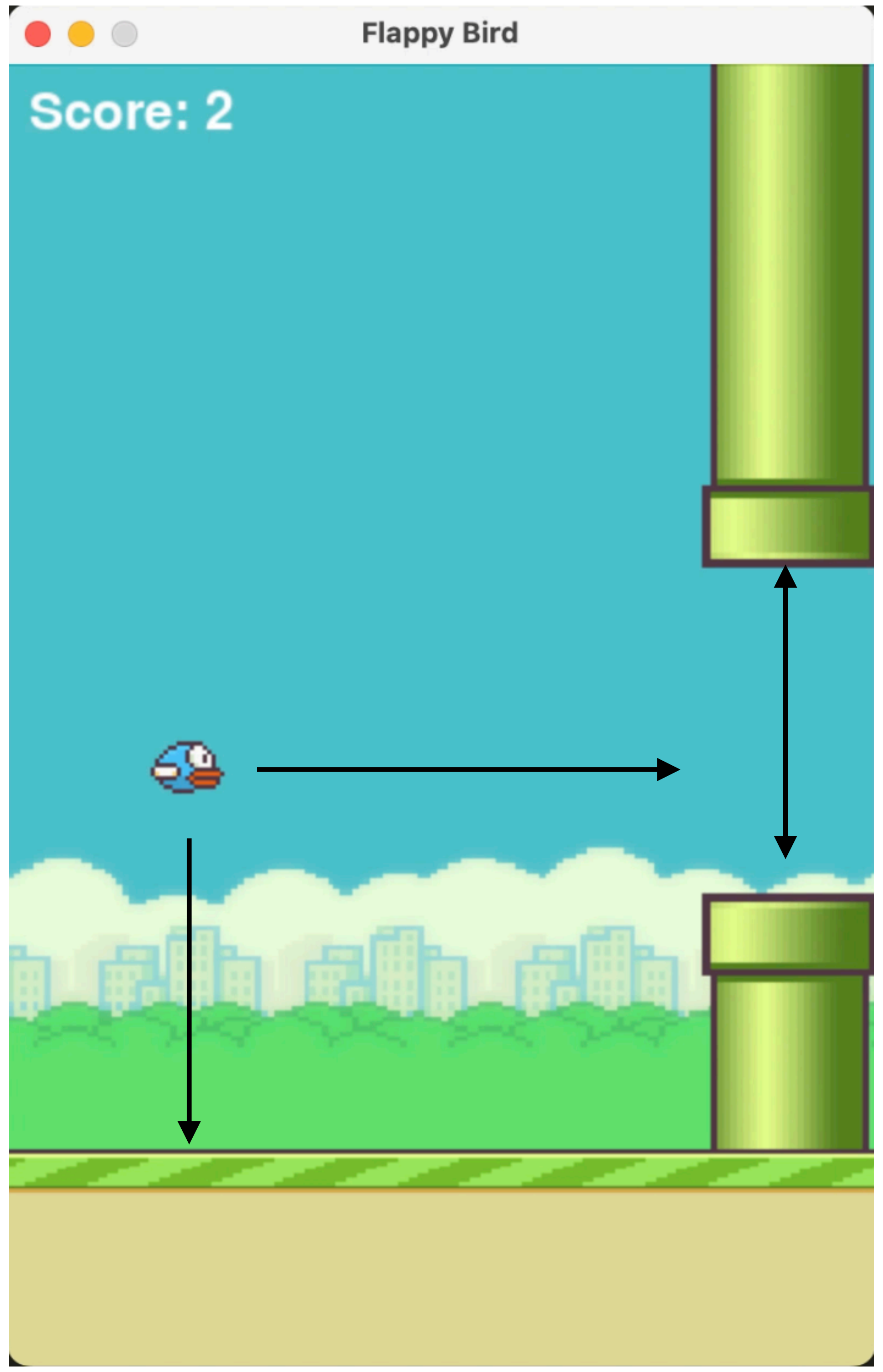


# Flappy Bird

## Is time important?

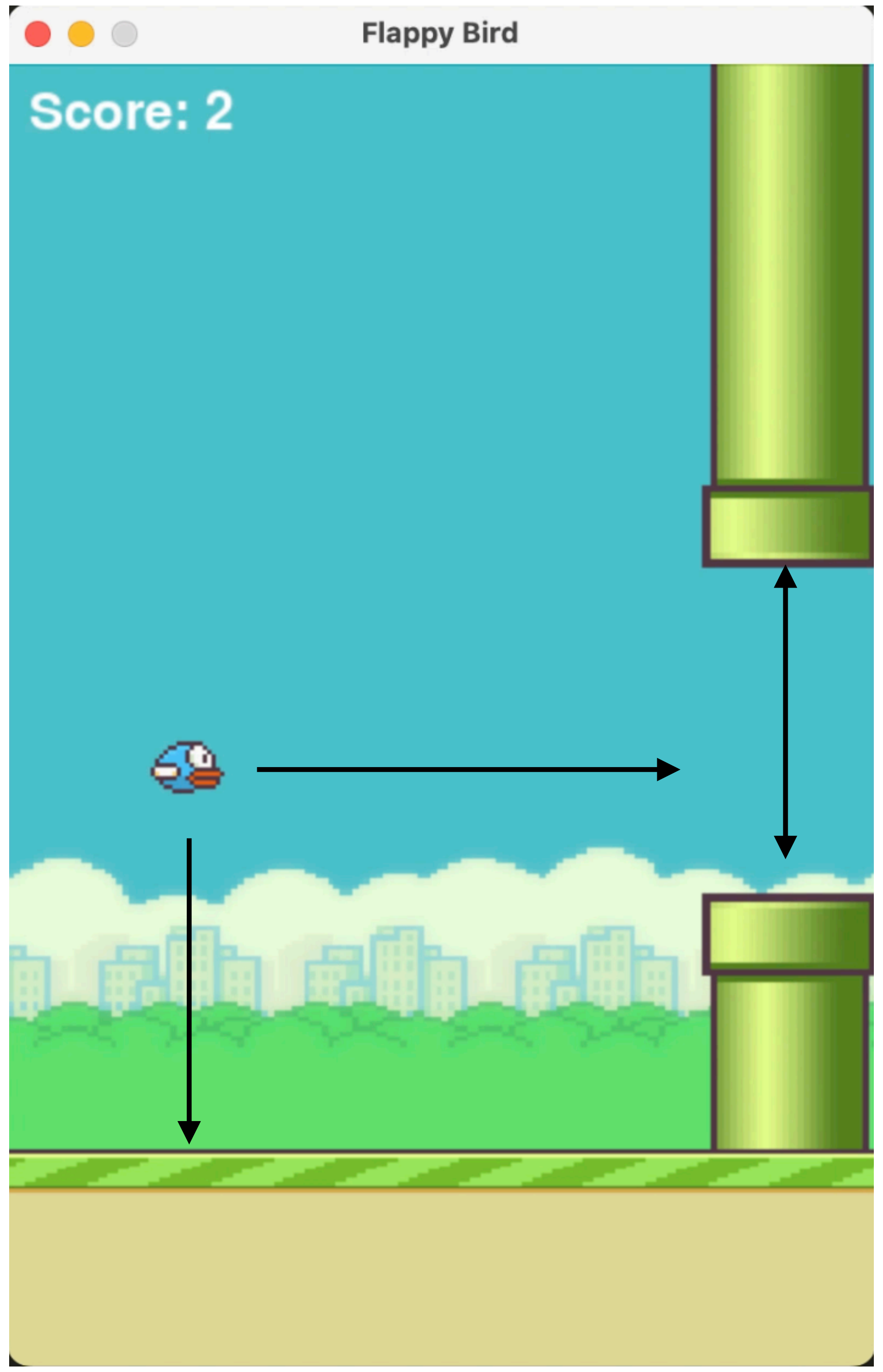


# Flappy Bird

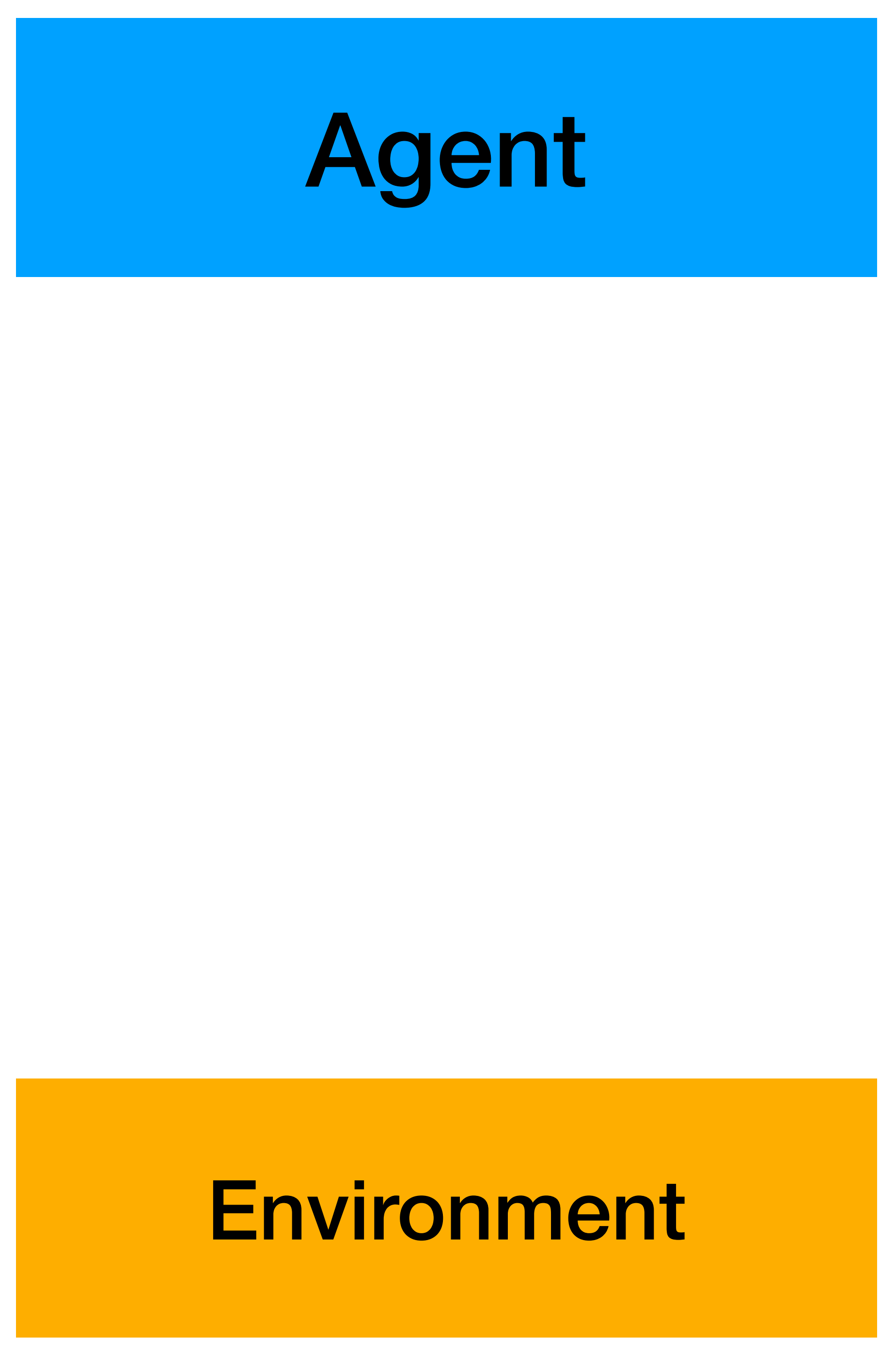
## Is time important?

**Yes**

Agent's current state depends on previous state and action



# Block Diagram



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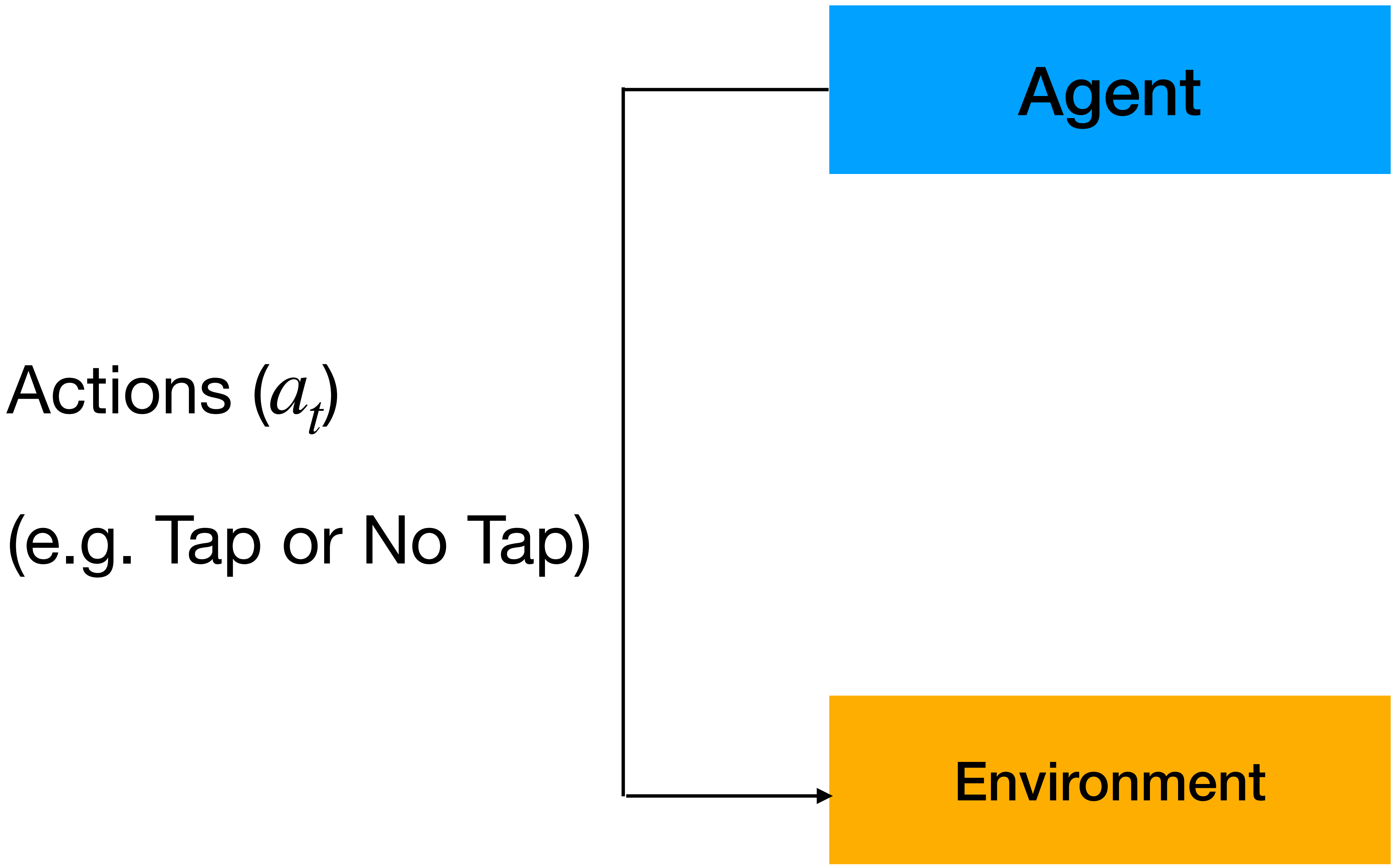

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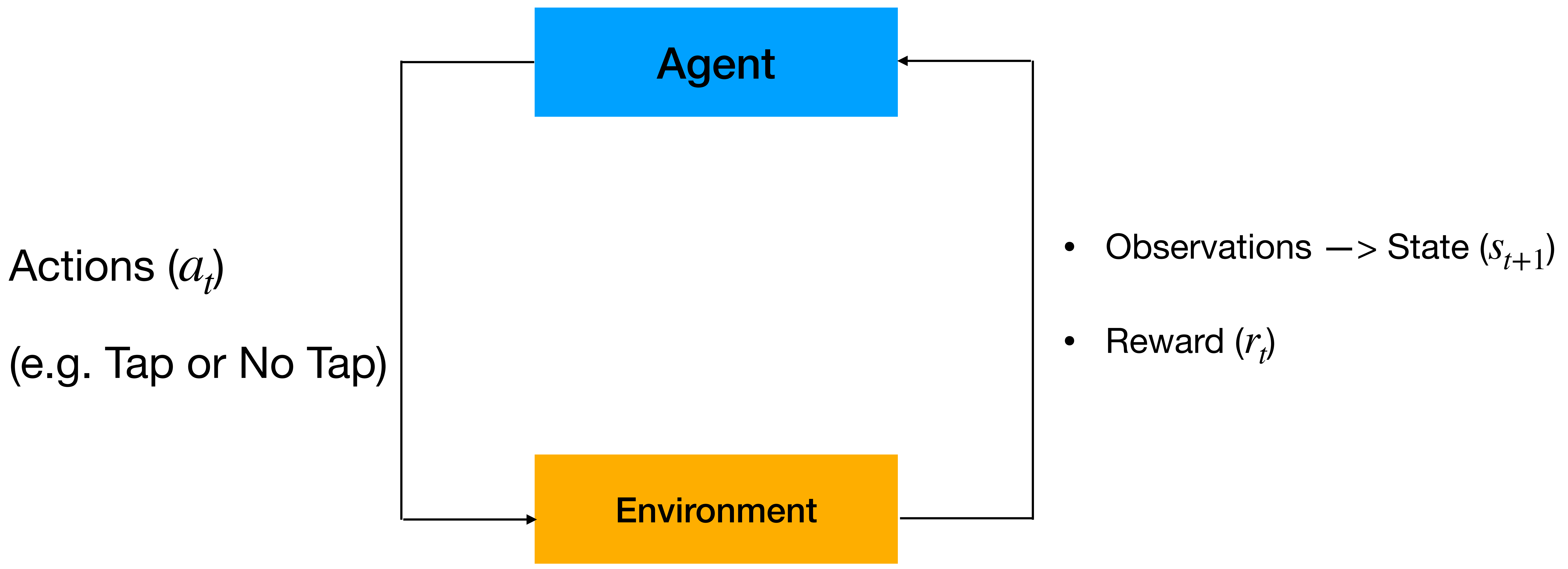
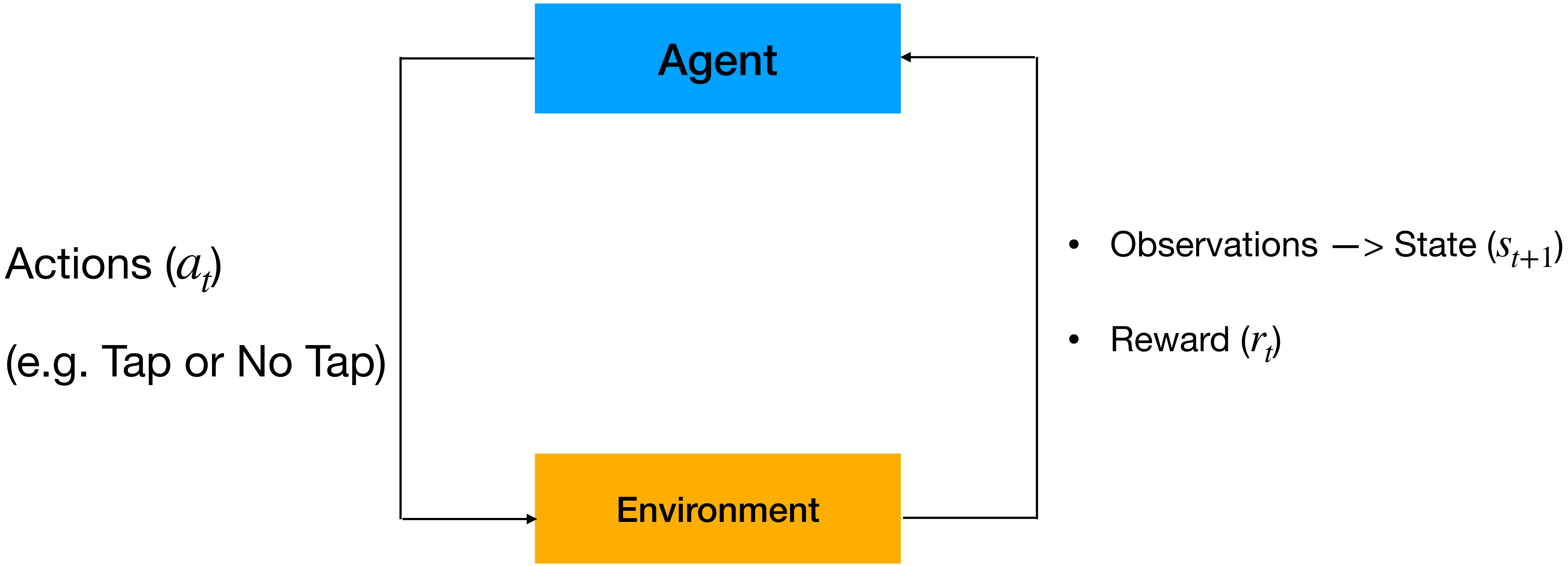


# OpenAI Gym Environment

- Mountain Car
  - Actions?
  - State?

# Block Diagram



# Goal: Maximise total (discounted) reward

- Total Reward (Return) $R_t = \sum_{i=t}^{\infty} r_i = r_t + r_{t+1} \ldots + r_{t+n} + \cdots$
- Total Reward (Discounted Return)

$$R_t = \sum_{i=t}^{\infty} \gamma^i r_i = \gamma^t r_t + \gamma^{t+1} r_{t+1} \ldots + \gamma^{t+n} r_{t+n} + \cdots$$

- $\gamma$ : discount factor; $0 < \gamma < 1$

# Q function

- What we want?
  - Given a state choose an "action" that maximises total discounted reward
- Total Reward (Discounted Return)

$$R_t = \sum_{i=t}^{\infty} \gamma^i r_i = \gamma^t r_t + \gamma^{t+1} r_{t+1} \ldots + \gamma^{t+n} r_{t+n} + \cdots$$

- $Q\left(s_t, a_t\right) = \mathbb{E}\left[R_t \mid s_t, a_t\right]$
- Q-function captures the expected total future reward an agent can achieve by taking an action.

# Q table

| State | Action 1 | Action 2 | Action 3 |
|---|---|---|---|
| S1 | 10 | 20 | 15 |
| S2 | 20 | 30 | 5 |
| ... | | | |
| SN | -5 | 10 | 20 |

# Q table

| State | Action 1 | Action 2 | Action 3 |
|---|---|---|---|
| S1 | 10 | 20 | 15 |
| S2 | 20 | 30 | 5 |
| … | | | |
| SN | -5 | 10 | 20 |

What action will you choose if you are in state S2?

# Q table

| State | Action 1 | Action 2 | Action 3 |
|---|---|---|---|
| **S1** | 10 | 20 | 15 |
| **S2** | 20 | **30** | 5 |
| **...** | | | |
| **SN** | -5 | 10 | 20 |

What action will you choose if you are in state S2?

Action 2 (as it gives us highest return)

# Q table

| State <Position, Velocity> | Action 1 | Action 2 | Action 3 |
|---|---|---|---|
| <-5, -2> | ? | ? | ? |
| … | ? | ? | ? |
| … | | | |
| … | ? | ? | ? |

How do we define states for problems like Mountain car where these numbers are not discrete?

# Q table

| State <Position, Velocity> | Action 1 | Action 2 | Action 3 |
|---|---|---|---|
| <[-5, -4], [-2, -1]> | ? | ? | ? |
| <[-5, -4], [—1, 0]> | ? | ? | ? |
| ... | | | |
| ... | ? | ? | ? |

How do we define states for problems like Mountain car where these numbers are not discrete?

Discretisation (notebook)

# Q function (revision)

- What we want?
  - Given a state choose an “action” that maximises total discounted reward
- Total Reward (Discounted Return)

$$R_t = \sum_{i=t}^{\infty} \gamma^i r_i = \gamma^t r_t + \gamma^{t+1} r_{t+1} \ldots + \gamma^{t+n} r_{t+n} + \cdots$$

- $Q\left(s_t, a_t\right) = \mathbb{E}\left[R_t \mid s_t, a_t\right]$
- Q-function captures the expected total future reward an agent can achieve by taking an action.

# Bellman Equation

The Bellman equation for Q-values is given by:

$$Q(s, a) = R(s, a) + \gamma \cdot \max_{a'} Q\left(s', a'\right)$$

where:

- $Q(s, a)$ is the Q-value of taking action
- $R(s, a)$ is the immediate reward of taking action $a$ in state $s$.
- $\gamma$ is the discount factor that determines the importance of future rewards.
- $s'$ is the next state after taking action $a$.
- $\max_{a'} Q\left(s', a'\right)$ is the maximum Q-value over all possible actions in state $s'$.

# Q-learning Update Bellman Equation

$$Q(s, a) = R(s, a) + \gamma \cdot \max_{a'} Q\left(s', a'\right)$$

Q-learning update rule is derived by using the Bellman equation in an iterative manner:

$$Q(s, a) \leftarrow Q(s, a) + \alpha \cdot \left(R(s, a) + \gamma \cdot \max_{a'} Q\left(s', a'\right) - Q(s, a)\right)$$

- $\alpha$ is the learning rate that controls the extent to which new information overrides old information.

- $R(s, a) + \gamma \cdot \max_{a'} Q\left(s', a'\right) - Q(s, a)$ is the temporal difference (TD) error, representing the discrepancy between the expected Q-value and the observed reward.