

lab10dl-2

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1 Laboratorio 10 - Deep Learning

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1. Librerías

```
[4]: !pip install gym numpy torch
```

```
Requirement already satisfied: gym in /usr/local/lib/python3.10/dist-packages (0.25.2)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (1.23.5)
Requirement already satisfied: torch in /usr/local/lib/python3.10/dist-packages (2.1.0+cu118)
Requirement already satisfied: cloudpickle>=1.2.0 in /usr/local/lib/python3.10/dist-packages (from gym) (2.2.1)
Requirement already satisfied: gym-notices>=0.0.4 in /usr/local/lib/python3.10/dist-packages (from gym) (0.0.8)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from torch) (3.12.4)
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.10/dist-packages (from torch) (4.5.0)
Requirement already satisfied: sympy in /usr/local/lib/python3.10/dist-packages (from torch) (1.12)
Requirement already satisfied: networkx in /usr/local/lib/python3.10/dist-packages (from torch) (3.2)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.10/dist-packages (from torch) (3.1.2)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages (from torch) (2023.6.0)
Requirement already satisfied: triton==2.1.0 in /usr/local/lib/python3.10/dist-packages (from torch) (2.1.0)
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from jinja2->torch) (2.1.3)
Requirement already satisfied: mpmath>=0.19 in /usr/local/lib/python3.10/dist-packages (from sympy->torch) (1.3.0)
```

2. Cree el entorno CartPole

```
[5]: import gym
```

```
env = gym.make('CartPole-v1')
```

/usr/local/lib/python3.10/dist-packages/gym/core.py:317: DeprecationWarning:
WARN: Initializing wrapper in old step API which returns one bool instead
of two. It is recommended to set `new_step_api=True` to use new step API. This
will be the default behaviour in future.

deprecation(
/usr/local/lib/python3.10/dist-
packages/gym/wrappers/step_api_compatibility.py:39: DeprecationWarning:
WARN: Initializing environment in old step API which returns one bool
instead of two. It is recommended to set `new_step_api=True` to use new step
API. This will be the default behaviour in future.

deprecation(
3. Definición de las redes en línea y de destino

```
[8]: import torch.nn as nn
```

```
#ff
```

```
class DQNNetwork(nn.Module):
```

```
    def __init__(self, input_dim, output_dim, hidden_dim=64):
```

```
        super(DQNNetwork, self).__init__()
```

```
        self.fc1 = nn.Linear(input_dim, hidden_dim)
```

```
        self.fc2 = nn.Linear(hidden_dim, output_dim)
```

```
    def forward(self, x):
```

```
        x = torch.relu(self.fc1(x))
```

```
        x = self.fc2(x)
```

```
        return x
```

```
#Creamos las dos redes. Tenemos la online y la de destino
```

```
online_network = DQNNetwork(env.observation_space.shape[0], env.action_space.n)
```

```
target_network = DQNNetwork(env.observation_space.shape[0], env.action_space.n)
```

```
target_network.load_state_dict(online_network.state_dict())
```

```
[8]: <All keys matched successfully>
```

4. Establecimiento de hiperparámetros:

```
[9]: # Hiperparámetros
```

```
num_episodes = 1000
```

```
batch_size = 64
```

```
gamma = 0.99
```

```
epsilon = 1.0
```

```
epsilon_min = 0.01
epsilon_decay = 0.995
target_update_frequency = 5
```

5. Selección de acciones ϵ -greedy:

```
[10]: import numpy as np

def epsilon_greedy_action(network, state, epsilon):
    if np.random.rand() < epsilon:
        return env.action_space.sample()
    else:
        with torch.no_grad():
            return torch.argmax(network(torch.tensor(state).float())).item()
```

6. Definición de la reproducción de la experiencia (experience replay):

```
[11]: from collections import deque
import random

class ReplayBuffer:
    def __init__(self, capacity):
        self.buffer = deque(maxlen=capacity)

    def push(self, state, action, reward, next_state, done):
        experience = (state, action, reward, next_state, done)
        self.buffer.append(experience)

    def sample(self, batch_size):
        return random.sample(self.buffer, batch_size)

    def __len__(self):
        return len(self.buffer)

replay_buffer = ReplayBuffer(10000)
```

7. Ciclo de entrenamiento:

```
[11]: import torch.optim as optim
import numpy as np
import torch

optimizer = optim.Adam(online_network.parameters(), lr=0.001)

for episode in range(num_episodes):
    state = env.reset()
```

```

episode_reward = 0
done = False

while not done:
    action = epsilon_greedy_action(online_network, state, epsilon)
    next_state, reward, done, _ = env.step(action)
    replay_buffer.push(state, action, reward, next_state, done)

    episode_reward += reward
    state = next_state

    if len(replay_buffer) > batch_size:
        experiences = replay_buffer.sample(batch_size)
        states, actions, rewards, next_states, dones = zip(*experiences)

        states = torch.tensor(states).float()
        actions = torch.tensor(actions).long().unsqueeze(-1)
        rewards = torch.tensor(rewards).float().unsqueeze(-1)
        next_states = torch.tensor(next_states).float()
        dones = torch.tensor(dones).float().unsqueeze(-1)

        current_q_values = online_network(states).gather(1, actions)
        next_q_values = target_network(next_states).max(dim=1)[0].
↪unsqueeze(-1)
        target_q_values = rewards + gamma * next_q_values * (1 - dones)

        loss = nn.functional.mse_loss(current_q_values, target_q_values)

        optimizer.zero_grad()
        loss.backward()
        optimizer.step()

    if episode % target_update_frequency == 0:
        target_network.load_state_dict(online_network.state_dict())

epsilon = max(epsilon_min, epsilon_decay * epsilon)
print(f"Episode {episode}: Total Reward: {episode_reward}")

```

```

<ipython-input-11-cb0c52dc0093>:26: UserWarning: Creating a tensor from a list
of numpy.ndarrays is extremely slow. Please consider converting the list to a
single numpy.ndarray with numpy.array() before converting to a tensor.
(Triggered internally at ../torch/csrc/utils/tensor_new.cpp:261.)
    states = torch.tensor(states).float()

```

```

Episode 0: Total Reward: 16.0
Episode 1: Total Reward: 11.0
Episode 2: Total Reward: 33.0
Episode 3: Total Reward: 13.0

```

Episode 4: Total Reward: 13.0
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Episode 6: Total Reward: 16.0
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Episode 8: Total Reward: 43.0
Episode 9: Total Reward: 13.0
Episode 10: Total Reward: 37.0
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Episode 903: Total Reward: 500.0
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Episode 997: Total Reward: 500.0
Episode 998: Total Reward: 500.0
Episode 999: Total Reward: 500.0

8. Representar el entorno

```
[12]: env.close()
```

9. Supervisar el entrenamiento

```
[13]: import matplotlib.pyplot as plt

rewards = []

for episode in range(num_episodes):
```

```

    rewards.append(episode_reward)

plt.plot(rewards)
plt.ylabel('Reward acumulado')
plt.xlabel('Episodio')
plt.title('Progreso del entrenamiento del agente DQN')
plt.show()

test_episodes = 10
test_rewards = []

for episode in range(test_episodes):
    state = env.reset()
    episode_reward = 0
    done = False

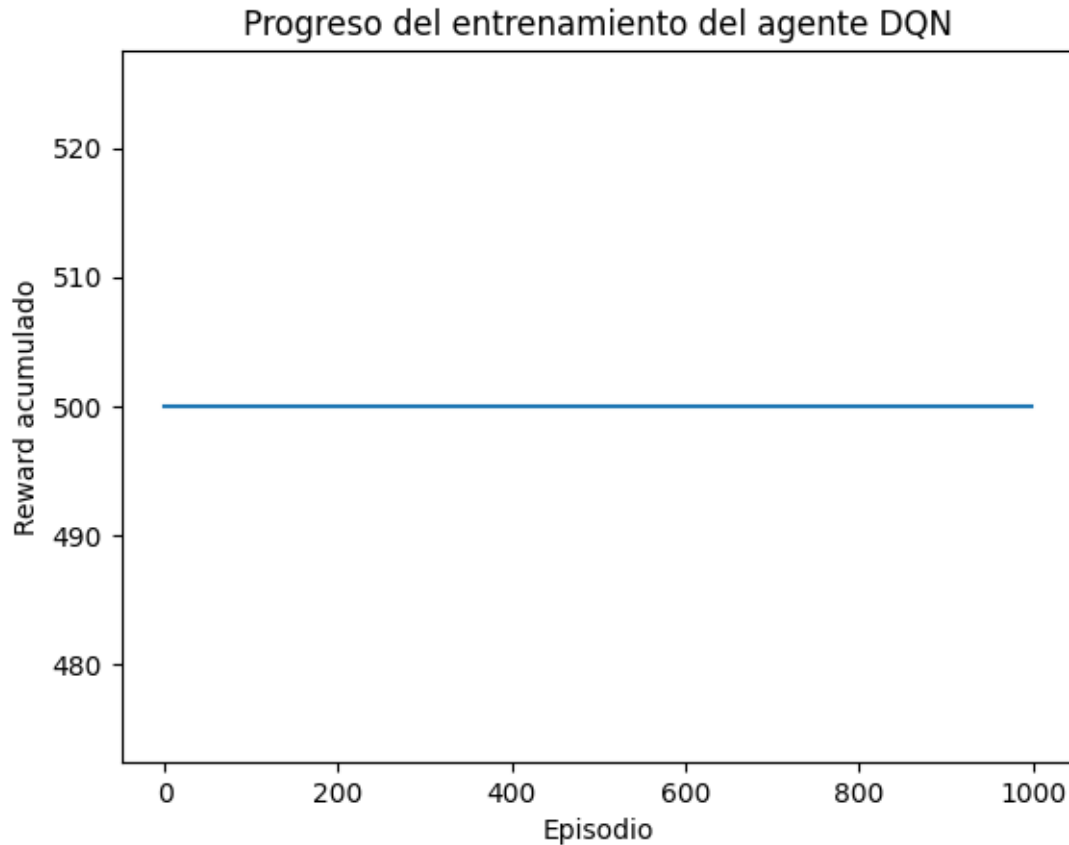
    while not done:
        action = torch.argmax(online_network(torch.tensor(state).float())).
        ↪item()
        next_state, reward, done, _ = env.step(action)
        episode_reward += reward
        state = next_state

    test_rewards.append(episode_reward)

average_test_reward = sum(test_rewards) / test_episodes
print(f"Recompensa promedio sobre {test_episodes} episodios de prueba: ↪
    ↪{average_test_reward}")

# Cerrando el entorno después de todo
env.close()

```



Recompensa promedio sobre 10 episodios de prueba: 420.2

Resultados

La recompensa que recibe el agente es +1 por cada paso que el poste se mantenga en equilibrio. Así que una recompensa de 420.2 significa que, en promedio, el agente logró mantener el poste en equilibrio durante 420.2 pasos en cada episodio de prueba.

El entorno CartPole de Gym se considera “resuelto” cuando el agente es capaz de conseguir una recompensa promedio de 195.0 durante 100 episodios consecutivos. Por lo que una recompensa promedio de 420.2 es mas que satisfactoria.

10. Evalúe el rendimiento

```
[13]: import matplotlib.pyplot as plt
import torch
import torch.nn as nn
import torch.optim as optim

device = 'cpu'

# Entrenar el modelo
```

```

rewards = []

num_episodes = 1000

for episode in range(num_episodes):
    state = env.reset()
    episode_reward = 0 # Inicializa la recompensa del episodio a 0 al
    ↪ principio de cada episodio
    done = False

    while not done:
        action = torch.argmax(online_network(torch.tensor(state).float().
    ↪ to(device))).item()
        next_state, reward, done, _ = env.step(action)
        episode_reward += reward # Acumula la recompensa para el episodio
        ↪ actual
        state = next_state

    rewards.append(episode_reward)

plt.figure(figsize=(12, 6))

plt.subplot(1, 2, 1)
plt.plot(rewards)
plt.ylabel('Reward acumulado')
plt.xlabel('Episodio')
plt.title('Progreso del entrenamiento del agente DQN')

# Evaluar el rendimiento después del entrenamiento
test_episodes = 100
test_rewards = []

for episode in range(test_episodes):
    state = env.reset()
    episode_reward = 0
    done = False

    while not done:
        action = torch.argmax(online_network(torch.tensor(state).float().
    ↪ to(device))).item()
        next_state, reward, done, _ = env.step(action)
        episode_reward += reward
        state = next_state

    test_rewards.append(episode_reward)

```

```

# Gráfica de la Recompensa en la Fase de Prueba
plt.subplot(1, 2, 2)
plt.plot(test_rewards)
plt.ylabel('Reward acumulado')
plt.xlabel('Episodio de prueba')
plt.title('Rendimiento en la fase de prueba')

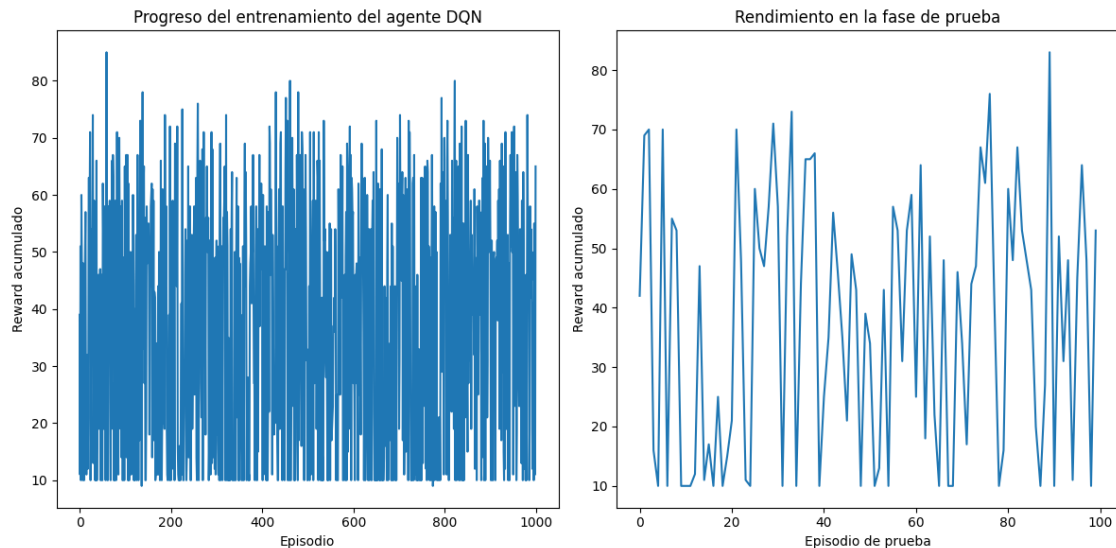
plt.tight_layout()
plt.show()

average_test_reward = sum(test_rewards) / test_episodes
print(f"Recompensa promedio sobre {test_episodes} episodios de prueba:␣
↪{average_test_reward:.2f}")

# Cerrando el entorno después de todo
env.close()

```

/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during the transform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
and should_run_async(code)



Recompensa promedio sobre 100 episodios de prueba: 37.40

11. Fine-Tuning

```
[14]: lr = 0.005 # Tasa de aprendizaje modificada
optimizer = optim.Adam(online_network.parameters(), lr=lr)
```

```
[15]: class DQN(nn.Module):
    def __init__(self, input_dim, output_dim):
        super(DQN, self).__init__()
        self.fc1 = nn.Linear(input_dim, 128)
        self.fc2 = nn.Linear(128, 256)
        self.fc3 = nn.Linear(256, 128)
        self.fc4 = nn.Linear(128, output_dim)

    def forward(self, x):
        x = torch.relu(self.fc1(x))
        x = torch.relu(self.fc2(x))
        x = torch.relu(self.fc3(x))
        return self.fc4(x)
```

```
[16]: batch_size = 64 # Nuevo tamaño del batch
```

```
[17]: gamma = 0.95 # Nuevo valor para gamma
```

```
[19]: input_dim = env.observation_space.shape[0]
output_dim = env.action_space.n
```

```
[25]: import torch.optim as optim
import matplotlib.pyplot as plt

device = "cpu"

online_network = DQNNetwork(input_dim, output_dim).to(device)
target_network = DQNNetwork(input_dim, output_dim).to(device)
target_network.load_state_dict(online_network.state_dict())

# Optimizador
optimizer = optim.Adam(online_network.parameters(), lr=0.001)

# Lista para almacenar recompensas por episodio
episode_rewards = []

for episode in range(num_episodes):

    epsilon = max(epsilon_min, epsilon_decay * epsilon)
    episode_rewards.append(episode_reward)
    print(f"Episode {episode}: Total Reward: {episode_reward}")

# Calcular el promedio móvil de las recompensas
```

```

N = 100
rolling_avg = [sum(episode_rewards[max(0, i-N):i+1])/(i+1) if i<N else
    ↳sum(episode_rewards[i-N:i+1])/N for i in range(len(episode_rewards))]

# Recompensa promedio durante todo el entrenamiento
average_reward = sum(episode_rewards) / len(episode_rewards)
print(f"Recompensa promedio durante todo el entrenamiento: {average_reward:.
    ↳2f}")

# Visualizaciones
fig, ax = plt.subplots(2, 1, figsize=(10, 8))

# Gráfico de recompensas por episodio
ax[0].plot(episode_rewards, label='Recompensa por episodio', color='blue')
ax[0].set_title('Recompensas por episodio')
ax[0].set_xlabel('Episodio')
ax[0].set_ylabel('Recompensa')
ax[0].legend()

# Gráfico del promedio móvil de las recompensas
ax[1].plot(rolling_avg, label=f'Promedio móvil ({N} episodios)',
    ↳color='orange', linestyle='--')
ax[1].set_title(f'Promedio móvil ({N} episodios)')
ax[1].set_xlabel('Episodio')
ax[1].set_ylabel('Recompensa')
ax[1].legend()

plt.tight_layout()
plt.show()

```

```

Episode 0: Total Reward: 204.0
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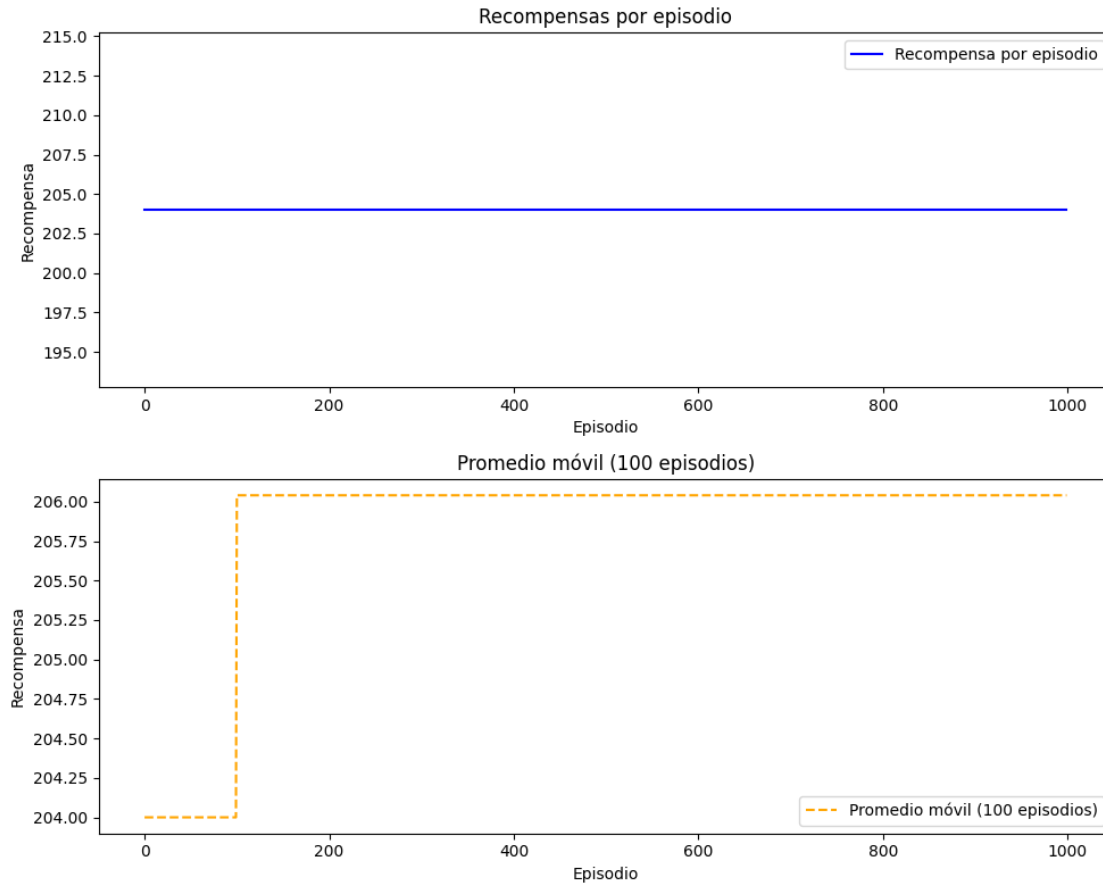
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Discusión

1.1 Task 2 - Teoría

Defina en qué consiste y en qué clase de problemas se pueden usar cada uno de los siguientes acercamientos en Deep Reinforcement Learning 1. Proximal Policy Optimization

Descripción: PPO es un método de optimización de políticas que modifica la función objetivo para entrenar una política actualizada, de manera que no se desvíe mucho de una política anterior. Lo hace mediante la introducción de un término de recorte en la función objetivo, lo que evita actualizaciones excesivamente grandes. Aplicaciones: PPO es útil para una variedad de problemas de RL, incluidos entornos con espacio de acción continuo y discreto. Ha sido ampliamente adoptado en la comunidad RL debido a su robustez y facilidad de implementación, y se ha utilizado con éxito en entornos como los de OpenAI Gym y robótica.

2. Deep Deterministic Policy Gradients (DDPG)

Descripción: DDPG es un algoritmo que combina ideas de Deep Q-Learning y política determinista basada en gradientes. Es un método actor-crítico, donde el actor produce una acción determinista y el crítico evalúa esa acción. DDPG utiliza memoria de repetición y redes objetivo para estabilizar el entrenamiento, similar a DQN.

Aplicaciones: DDPG es particularmente adecuado para entornos con espacios de acción continua, lo que lo hace útil para aplicaciones como el control de robótica y tareas que requieren una gran precisión en las acciones.

3. Trust Region Policy Optimization (TRPO)

Descripción: TRPO es un algoritmo de optimización de políticas que garantiza que las actualizaciones a la política no cambien la política anterior más allá de un cierto límite definido. Lo hace optimizando una función objetivo sujeto a una restricción que limita la variación de la política.

Aplicaciones: Similar a PPO, TRPO es adecuado para una amplia variedad de problemas de RL. Sin embargo, TRPO puede ser más complicado de implementar y computacionalmente más intensivo que PPO debido a la necesidad de realizar optimización con restricciones.

4. Asynchronous Advantage Actor-Critic (A3C)

Descripción: A3C es un método de aprendizaje por refuerzo que utiliza múltiples agentes que se ejecutan en paralelo en múltiples instancias del entorno. Estos agentes actualizan de manera asincrónica una política global. El método combina ideas de “Advantage Actor-Critic” (una variante de métodos actor-crítico) y entrenamiento asíncrono.

Aplicaciones: A3C es adecuado para una amplia gama de problemas de RL y ha mostrado un rendimiento impresionante en tareas como el conjunto de juegos de Atari. Debido a su enfoque paralelo, puede ser más eficiente en términos de tiempo de entrenamiento que algunos otros métodos, dependiendo de la infraestructura disponible.