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ОТЧЕТ

Лабораторная работа №__6__
по дисциплине «Методы машинного обучения»

Тема: «Обучение на основе глубоких Q-сетей»

ИСПОЛНИТЕЛЬ: Лу Сяои
ФИО

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подпись

"10" Июнь 2023 г.

ПРЕПОДАВАТЕЛЬ:
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ФИО

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подпись

"__"__________2023 г.

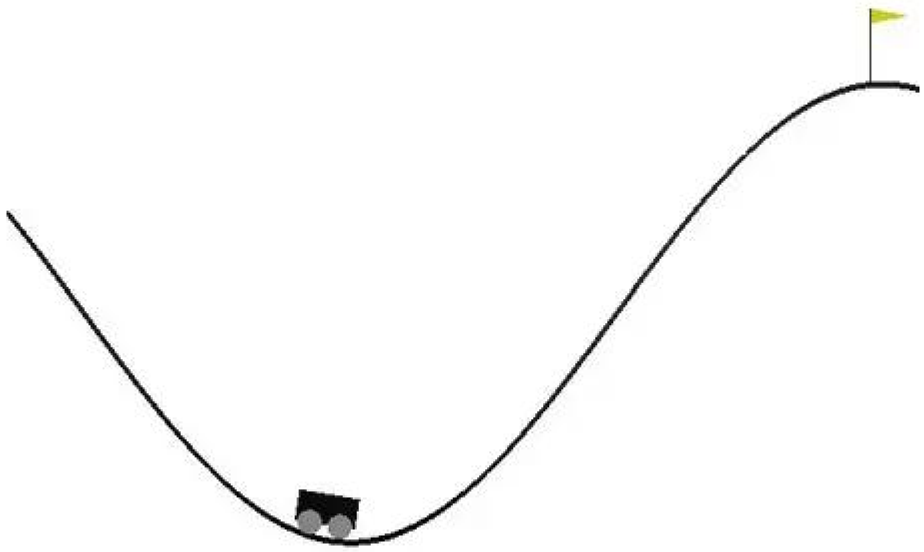
Москва - 2023

описание задания

На основе рассмотренного на лекции примера реализуйте алгоритм **Policy Iteration** для любой среды обучения с подкреплением (кроме рассмотренной на лекции среды Toy Text / Frozen Lake) из библиотеки Gym (или аналогичной библиотеки).

текст программы и экранные формы с примерами выполнения программы.

Я выбрала среду **MountainCar-v0**.



Observation

Type: Box(2)

Num	Observation	Min	Max
0	Car Position	-1.2	0.6
1	Car Velocity	-0.07	0.07

Note that velocity has been constrained to facilitate exploration, but this constraint might be relaxed in a more challenging version.

Actions

Type: Box(1)

Num	Action
0	Push car to the left (negative value) or to the right (positive value)

Reward

Reward is 100 for reaching the target of the hill on the right hand side, minus the squared sum of actions from start to goal.

This reward function raises an exploration challenge, because if the agent does not reach the target soon enough, it will figure out that it is better not to move, and won't find the target anymore.

```
import gym
import random
import numpy as np
import copy
import matplotlib.pyplot as plt
from collections import namedtuple, deque
import torch
import torch.nn as nn
import torch.optim as optim
import torch.nn.functional as F
import warnings
warnings.filterwarnings("ignore")
```

```
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

env = gym.make('MountainCar-v0')
n_actions = env.action_space.n
n_states = env.observation_space.shape[0]
```

```
Transition = namedtuple('Transition', ('state', 'action', 'next_state', 'reward', 'done'))
```

Буфер для experience replay

```
class ReplayMemory(object):
    def __init__(self, capacity):
        self.capacity = capacity
        self.memory = []
        self.position = 0

    def push(self, *args):
        """Saves a transition."""
        if len(self.memory) < self.capacity:
            self.memory.append(None)
        self.memory[self.position] = Transition(*args)
        self.position = (self.position + 1) % self.capacity
```

```
    def sample(self, batch_size):
        return random.sample(self.memory, batch_size)
```

```
    def __len__(self):
        return len(self.memory)
```

Класс для DQN

```
class DQN:
    def __init__(self, layers, lr=0.0005, optim_method=optim.Adam):
        self.layers = layers
        self.lr = lr
        self.loss = F.mse_loss
        self.optim_method = optim_method
        self.TargetNetwork = None
        self.EstimateNetwork = None
        self.optimizer = None
        self.build_model()

    def build_model(self):
        def init_weights(layer):
            if type(layer) == nn.Linear:
                nn.init.xavier_normal_(layer.weight)
```

```
        self.EstimateNetwork = nn.Sequential(*self.layers)
        self.EstimateNetwork.apply(init_weights)
```

```
        layers_for_target = copy.deepcopy(self.layers)
        self.TargetNetwork = nn.Sequential(*layers_for_target)
        self.TargetNetwork.load_state_dict(self.EstimateNetwork.state_dict())

        self.optimizer = self.optim_method(self.EstimateNetwork.parameters(), lr=self.lr)

    def Q_target(self, inp):
        return self.TargetNetwork(inp)

    def Q_estimate(self, inp):
        return self.EstimateNetwork(inp)

    def update_target(self):
        self.TargetNetwork.load_state_dict(self.EstimateNetwork.state_dict())

    def update_parameters(self, estimated, targets):
        loss = self.loss(estimated, targets.unsqueeze(1))
        self.optimizer.zero_grad()
        loss.backward()

        for param in self.EstimateNetwork.parameters():
            param.grad.data.clamp_(-1, 1)
        self.optimizer.step()

    def save(self, name):
        torch.save(self.EstimateNetwork, name)
        print('------ Model saved ------')
```

Класс для агента

```
class Agent:
    def __init__(self, env, Model, n_actions, goal, min_score, \
                 eps_start=1, eps_end=0.001, eps_decay=0.9, gamma=0.99, \
                 batch_size=64, memory_size=100000, max_episode=2000, upd_rate=1):
        self.env = env
        self.n_actions = n_actions # number of possible actions
        self.goal = goal # the score to reach during learning
        self.min_score = min_score # min score to complete the episode
        self.eps_start = eps_start
        self.eps = eps_start
        self.eps_end = eps_end
        self.eps_decay = eps_decay
        self.gamma = gamma
        self.batch_size = batch_size
        self.target_update_rate = upd_rate # how often we update our target network
        self.Model = Model # DQN instance
        self.max_episode = max_episode # how long we train our agent
        self.memory = ReplayMemory(memory_size) # Replay buffer

    def act(self, state, eps): # epsilon greedy policy
        if random.random() < eps:
            return torch.tensor([[random.randrange(self.n_actions)]], device=device, dtype=torch.long)
        else:
            with torch.no_grad():
                result = self.Model.Q_estimate(state).max(1)[1]
                return result.view(1, 1)

    def optimize(self): # experience replay
        if len(self.memory) < self.batch_size:
            return
```

```
        transitions = self.memory.sample(self.batch_size)
        batch = Transition(*zip(*transitions))

        next_state_batch = torch.cat(batch.next_state)
        state_batch = torch.cat(batch.state)
        action_batch = torch.cat(batch.action)
        reward_batch = torch.cat(batch.reward)
        done_batch = torch.cat(batch.done)

        estimate_value = self.Model.Q_estimate(state_batch).gather(1, action_batch)

        Q_value_next = torch.zeros(self.batch_size, device=device)
        with torch.no_grad():
            Q_value_next[~done_batch] = self.Model.Q_target(next_state_batch).max(1)[0].detach()[~done_batch]
        target_value = (Q_value_next * self.gamma) + reward_batch

        self.Model.update_parameters(estimate_value, target_value)

    def train(self): # learning procedure
        all_scores = []
        successful_sequences = 0
        for ep in range(1, self.max_episode + 1):
            state = self.env.reset()
            state = torch.tensor(state).to(device).float().unsqueeze(0)
            done = False
            episode_reward = 0

            while not done:
                action = self.act(state, self.eps)
                action = torch.tensor(action).to(device)

                next_state, reward, done, info = self.env.step(action.item())
                episode_reward += reward

                modified_reward = reward + 300 * (self.gamma * abs(next_state[1]) - abs(state[0][1]))

                next_state = torch.tensor(next_state).to(device).float().unsqueeze(0)
                modified_reward = torch.tensor(modified_reward).to(device).float().unsqueeze(0)
                done = torch.tensor(done).to(device).unsqueeze(0)

                self.memory.push(state, action, next_state, modified_reward, done)
                state = next_state

                self.optimize() # experience replay


            if ep % self.target_update_rate == 0:
                self.Model.update_target()

            self.eps = max(self.eps_end, self.eps * self.eps_decay)
            all_scores.append(episode_reward)

            if ep % 100 == 0:
                print('episode', ep, ':', np.mean(all_scores[:-100:-1]), 'average score')

            if np.mean(all_scores[:-100:-1]) >= self.goal:
                successful_sequences += 1
                if successful_sequences == 5:
                    print('success at episode', ep)
```

```
                return all_scores
            else:
                successful_sequences = 0

        return all_scores

    def test(self, episodes=50, render=False): #test trained agent
        state = self.env.reset()
        state = torch.tensor(state).to(device).float().unsqueeze(0)
        ep_count = 0
        current_episode_reward = 0
        scores = []
        while ep_count < episodes:
            if render:
                env.render()
            action = self.act(state, 0)
            state, reward, done, _ = self.env.step(action.item())
            state = torch.tensor(state).to(device).float().unsqueeze(0)
            current_episode_reward += reward

            if done:
                ep_count += 1
                scores.append(current_episode_reward)
                current_episode_reward = 0
                state = self.env.reset()
                state = torch.tensor(state).to(device).float().unsqueeze(0)

        print('average score:', sum(scores) / len(scores))
        print('max reward:', max(scores))
        print('-----')
        print()

    def save(self, name='agent.pkl'): # save policy network
        self.Model.save(name)
```

Инициализация агента и обучение

Используется трехслойная нейронная сеть с прямой связью, состоящая из двух полностью связанных слоев и одного выходного слоя.
Первый слой - входной слой, содержащий n_состояний входных узлов, второй и третий слои - скрытые слои, содержащие по 256 нейронов, и последний слой - выходной слой, содержащий n_действий выходных узлов.

```
layers = (
    nn.Linear(n_states, 256),
    nn.ReLU(),
    nn.Linear(256, 256),
    nn.ReLU(),
    nn.Linear(256, n_actions),
)

Model = DQN(layers, lr=0.0001, optim_method=optim.Adam)
MountainCarAgent = Agent(env, Model, n_actions, goal=-110, min_score=-200, \
                    eps_start=1, eps_end=0.001, eps_decay=0.9, gamma=0.99, \
                    batch_size=64, memory_size=100000, max_episode=2000)
scores = MountainCarAgent.train()
```

```
episode 100 : -194.11111111111111 average score
episode 200 : -189.46464646464648 average score
episode 300 : -200.0 average score
episode 400 : -195.36363636363637 average score
episode 500 : -188.26262626262627 average score
episode 600 : -160.37373737373738 average score
episode 700 : -160.86868686868686 average score
episode 800 : -141.02020202020202 average score
episode 900 : -111.65656565656566 average score
success at episode 919
```

Протестируем агента и выведем средний скор за 100 эпизодов

```
MountainCarAgent.test(episodes=100)
```

```
average score: -102.77
max reward: -85.0
-----
```

История обучения

```
episodes = range(len(scores))
plt.plot(episodes, scores)
plt.xlabel('episodes')
plt.ylabel('scores')
plt.show()
```