Introduction to Reinforcement Learning

OCNC 2019

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
```

Classes for minimum environment and agent

In [2]:
```
class Environment:
    """Class for a reinforcement learning environment"""

    def __init__(self, nstate=3, naction=2):
        """Create a new environment"""
        self.Ns = nstate   # number of states
        self.Na = naction  # number of actions

    def start(self):
        """start an episode"""
        # randomly pick a state
        self.state = np.random.randint(self.Ns)
        return self.state

    def step(self, action):
        """step forward given an action"""
        # random reward
        self.reward = np.random.random()  # between 0 and 1
        # random state transition
        self.state = np.random.randint(self.Ns)
        return self.reward, self.state
```

In [3]:
```
class Agent:
    """Class for a reinforcement learning agent"""

    def __init__(self, nstate, naction):
        """Create a new agent"""
        self.Ns = nstate   # number of states
        self.Na = naction  # number of actions

    def start(self, state):
        """first action, without reward feedback"""
        # randomly pick an action
        self.action = np.random.randint(self.Na)
        return self.action

    def step(self, reward, state):
        """learn by reward and take an action"""
        # do nothing for reward
        # randomly pick an action
        self.action = np.random.randint(self.Na)
        return self.action
```

In [4]:
```
class RL:
    """Reinforcement learning by interacton of Environment and Agen
    
    def __init__(self, environment, agent, nstate, naction):
        """Create the environment and the agent"""
        self.env = environment(nstate, naction)
        self.agent = agent(nstate, naction)

    def episode(self, tmax=50):
        """One episode"""
        # First contact
        state = self.env.start()
        action = self.agent.start(state)
        # Table of t, r, s, a
        Trsa = np.zeros((tmax+1,4))
        Trsa[0,:] = [0, 0, state, action]
        # Repeat interactoin
        for t in range(1, tmax+1):
            reward, state = self.env.step(action)
            action = self.agent.step(reward, state)
            Trsa[t,:] = [t, reward, state, action]
        return Trsa

    def run(self, nrun=10, tmax=50):
        """Multiple runs of episodes"""
        Return = np.zeros(nrun)
        for n in range(nrun):
            r = self.episode(tmax)[:,1]  # reward sequence
            Return[n] = sum(r)
        return Return
```

Q learning of Pain-Gain task

In [5]:

```
class PainGain(Environment):
    """Pain-Gain environment """

    def __init__(self, nstate=4, naction=2, gain=6):
        super().__init__(nstate, naction)
        # setup the reward function as an array
        self.R = np.ones((self.Ns, self.Na))
        self.R[:,1] = -1   # small pains for action 1
        self.R[0,0] = -gain  # large pain
        self.R[-1,1] = gain  # large gain

    def step(self, action):
        """step by an action"""
        self.reward = self.R[self.state, action]  # reward
        self.state = (self.state + 2*action-1)%self.Ns  # move lef
        return(self.reward, self.state)
```

In [6]:
```
class QL(Agent):
    """Class for a Q-learning agent"""

    def __init__(self, nstate, naction):
        super().__init__(nstate, naction)
        # allocate Q table
        self.Q = np.zeros((nstate, naction))
        # default parameters
        self.alpha = 0.1  # learning rate
        self.beta = 2.0   # inverse temperature
        self.gamma = 0.9  # discount factor

    def boltzmann(self, q):
        """Boltzmann selection"""
        pa = np.exp( self.beta*q)   # unnormalized probability
        pa = pa/sum(pa)    # normalize
        return np.random.choice(self.Na, p=pa)

    def start(self, state):
        """first action, without reward feedback"""
        # Boltzmann action selection
        self.action = self.boltzmann( self.Q[state,:])
        # remember the state
        self.state = state
        return self.action

    def step(self, reward, state):
        """learn by reward and take an action"""
        # TD error: self.state/action retains the previous ones
        delta = reward + self.gamma*max(self.Q[state,:]) - self.Q[
        # Update the value for previous state and action
        self.Q[self.state,self.action] += self.alpha*delta
        # Boltzmann action selection
        self.action = self.boltzmann( self.Q[state,:])
        # remember the state
        self.state = state
        return self.action
```

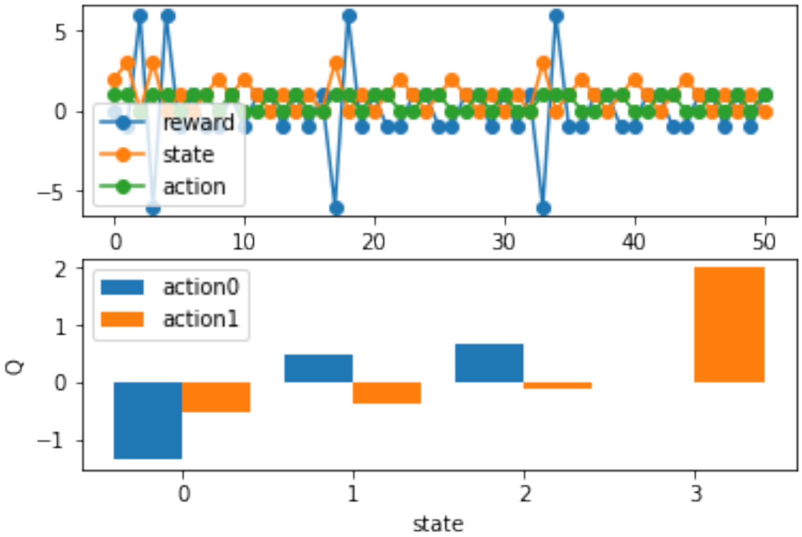
Setup and Run

In [7]:
```
# Setup Pain-Gain environment and Q-learning agent
pgq = RL(PainGain, QL, 4, 2)
pgq.env.R
```

Out[7]:
```
array([[-6., -1.],
       [ 1., -1.],
       [ 1., -1.],
       [ 1.,  6.]])
```

In [8]:

```
# Run an episode of 50 trials
trsa = pgq.episode(50)
# plot the time course of state, action, reward,
plt.subplot(2,1,1)
plt.plot(trsa[:,1:], "o-")
plt.legend(["reward", "state", "action"])
plt.xlabel("time")
# plot the action values
plt.subplot(2,1,2)
plt.bar(np.arange(pgq.agent.Ns)-0.2, pgq.agent.Q[:,0], 0.4)  # act
plt.bar(np.arange(pgq.agent.Ns)+0.2, pgq.agent.Q[:,1], 0.4)  # act
plt.legend(["action0", "action1"]);
plt.xticks(range(pgq.agent.Ns)); plt.xlabel("state"); plt.ylabel("
```



In [9]:

```
# reduce the discount factor
pgq.agent.gamma = 0.3
```

In [10]:

```
# restore the discount factor
pgq.agent.gamma = 0.9
```

In [11]:

```
# increase the inverse temperature
pgq.agent.beta = 10
```

In [12]:

```
# reduce the inverse temperature
pgq.agent.beta = 1
```

In [ ]:

```

```

In [ ]:

```

```