bandits

February 28, 2021

1 TME 1: bandits

Énoncé: http://dac.lip6.fr/master/wp-content/uploads/2019/09/TME1.pdf

Données: http://dac.lip6.fr/master/wp-content/uploads/2019/06/CTR.txt

[1]:

```python
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
```

2 Data loading

[2]:

```python
df = pd.read_csv('CTR.txt', sep="\s+|;|:", header=None)
```

```
/home/theophile/.m2a/lib/python3.7/site-packages/ipykernel_launcher.py:1:
ParserWarning: Falling back to the 'python' engine because the 'c' engine does
not support regex separators (separators > 1 char and different from '\s+' are
interpreted as regex); you can avoid this warning by specifying engine='python'.
  """Entry point for launching an IPython kernel.
```

[3]:

```python
class Data:
    def __init__(self, dataframe):
        self.gains = np.array(dataframe.loc[:, 6:])
        self.context = np.array(dataframe.loc[:, 1:5])
        self.cur = 0
        self.N = dataframe.shape[0]
        self.d = 5
        self.N_arms = 10

        # Compute optimal arm
        self.det_choice = np.argmax(np.mean(self.context, axis=0))

    def get(self, i):
        """Return ith data entry for context, gains."""
        return self.context[i], self.gains[i]
```

[4]:

```
d = Data(df)
```

Look at pages in order for different algorithms

3 Baselines

[5]:

```
class Bandit:

    def __init__(self, data):

        self.data = data
        self.N = data.N
        self.N_arms = data.N_arms

        self.arms = np.arange(0, self.N_arms, dtype=np.int64)

        # Compute static choice (mu^*)
        self.static_choice = np.argmax(np.mean(self.data.context, axis=0))

        # History
        #NB float128 "nécessaire" car sinon, il y a overflow.
        self.gains = np.zeros(self.N, dtype=np.float128)
        self.max_gains = np.zeros(self.N, dtype=np.float128)
        self.static_gains = np.zeros(self.N, dtype=np.float128)

        # Strategy accumulators
        self.mu = np.zeros(self.N_arms, dtype=np.float128)
        self.s = np.zeros(self.N_arms, dtype=np.float128)

        self.cur = 0 # current time step


    def initialize(self):
        """Choose each arm once to initialize estimates."""
        for arm in self.arms:
            context, gains = self.data.get(self.cur)
            chosen_arm, gain = self.choose(context, gains, arm=arm)
            self.save_history(gain, gains)
            self.update(chosen_arm, context, gain)


    def choose(self, context, gains, arm=None):
        """Choose action from context and history.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        raise NotImplementedError


    def update(self, arm, context, gain):
        raise NotImplementedError


    def save_history(self, gain, gains):
        """Save histories of gains, max_gains and static_gains."""
        self.gains[self.cur] = gain
        self.max_gains[self.cur] = np.max(gains)
        self.static_gains[self.cur] = gains[self.static_choice]


    def run(self):
        self.initialize()
        for i in range(self.arms.size, self.N):
            context, gains = self.data.get(self.cur)
            arm, gain = self.choose(context, gains)
            self.save_history(gain, gains)
            self.update(arm, context, gain)


    def pseudo_regret(self):
        return np.cumsum(self.max_gains - self.gains)


    def regret(self):
        return np.cumsum(self.static_gains - self.gains)

    def average_regret(self):
        return self.regret() / np.arange(1, self.N + 1)

    def average_pseudo_regret(self):
        return self.pseudo_regret() / np.arange(1, self.N + 1)
```

[6]:
```
c = Bandit(d)
```

[7]:
```
class RandomBandit(Bandit):

    def __init__(self, data):

        super().__init__(data)


    def initialize(self):
```

```python
        """Choose each arm once to initialize estimates."""
        for arm in self.arms:
            context, gains = self.data.get(self.cur)
            chosen_arm, gain = self.choose(context, gains, arm=arm)
            self.save_history(gain, gains)
            self.update(chosen_arm, context, gain)


    def choose(self, context, gains, arm=None):
        """Choose action from context and history.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        if arm is None:
            arm = np.random.choice(self.arms)
        return arm, gains[arm]


    def update(self, arm, context, gain):
        self.cur += 1
```

[8]:

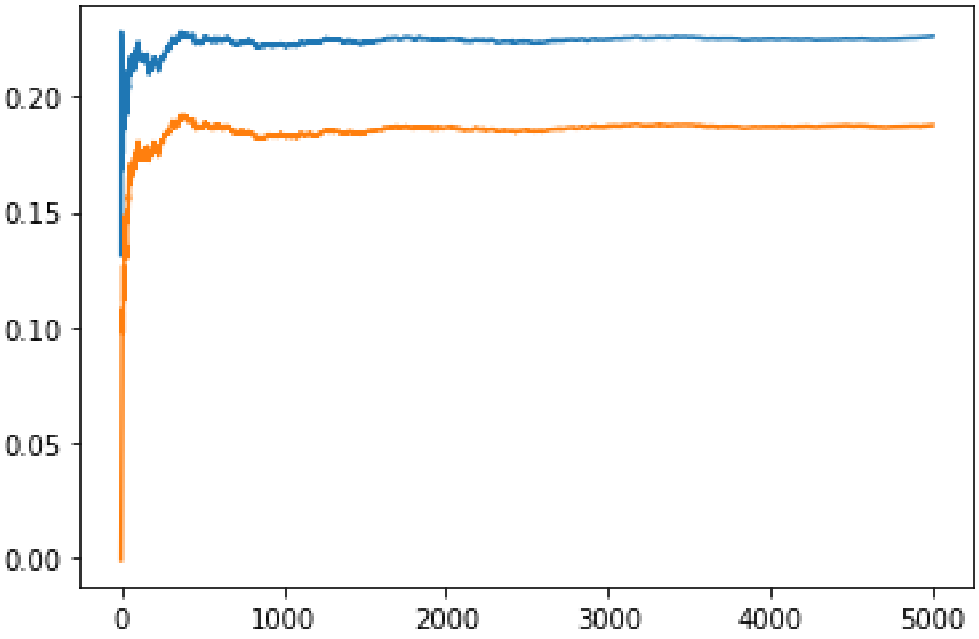
```python
r = RandomBandit(d)
r.run()
```

[9]:

```python
plt.plot(r.average_pseudo_regret())
plt.plot(r.average_regret())
```

[9]:

```
[<matplotlib.lines.Line2D at 0x7f9d2da82d10>]
```

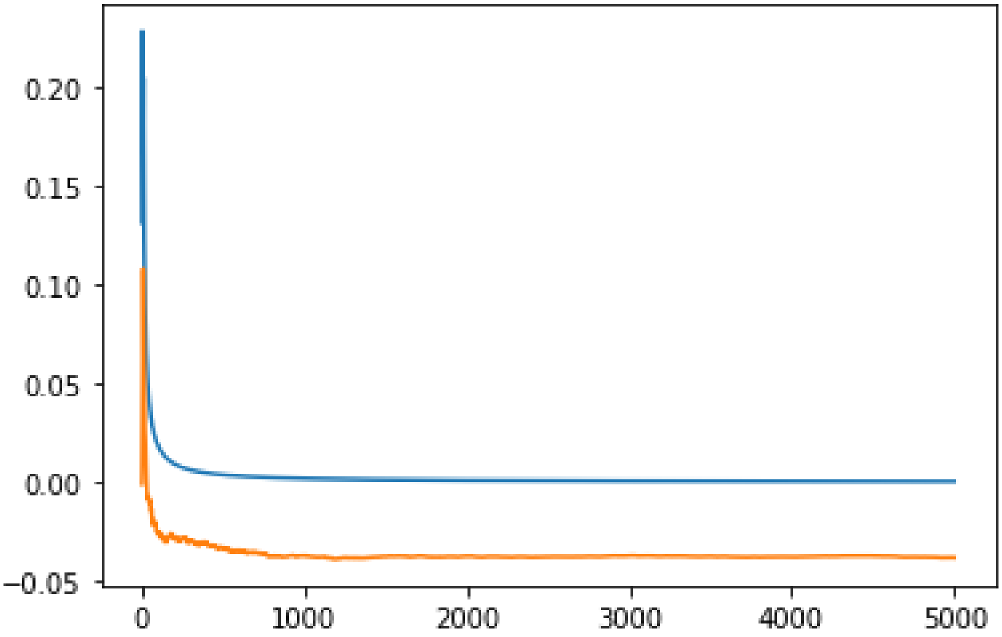


[10]:

```
class OptimalBandit(Bandit):

    def __init__(self, data):

        super().__init__(data)


    def initialize(self):
        """Choose each arm once to initialize estimates."""
        for arm in self.arms:
            context, gains = self.data.get(self.cur)
            chosen_arm, gain = self.choose(context, gains, arm=arm)
            self.save_history(gain, gains)
            self.update(chosen_arm, context, gain)


    def choose(self, context, gains, arm=None):
        """Choose action from context and history.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        if arm is None:
            arm = np.argmax(gains)
        return arm, gains[arm]
    def update(self, arm, context, gain):
        self.cur += 1
```

```
[11]: opt = OptimalBandit(d)
      opt.run()
      plt.plot(opt.average_pseudo_regret())
      plt.plot(opt.average_regret())
```

```
[11]: [<matplotlib.lines.Line2D at 0x7f9d2d9b2c10>]
```



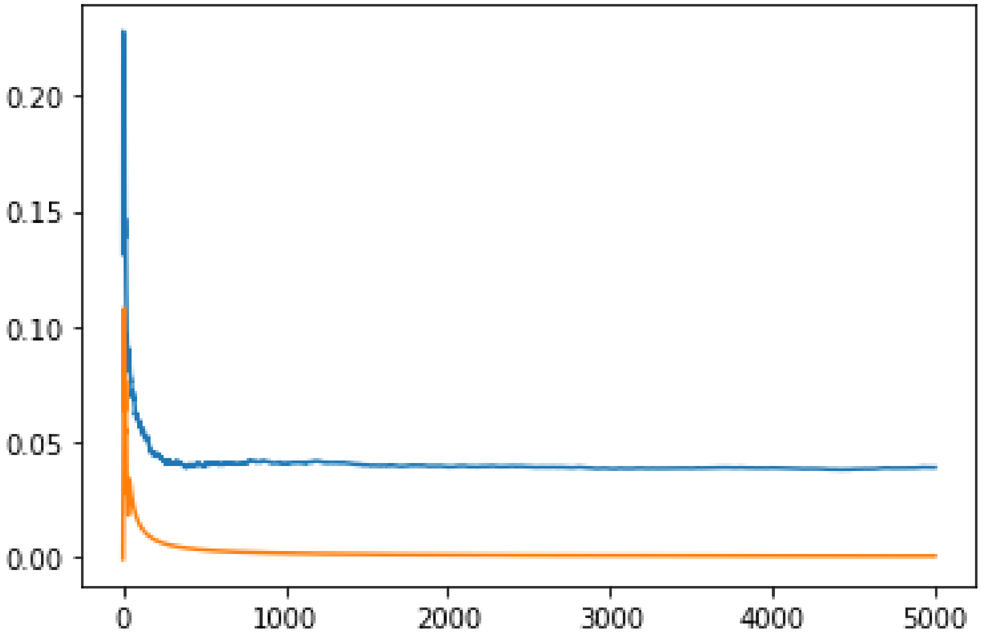
Note: negative regret because uses contextual information.

```
[12]: # The staticbest strategy is equivalent to epsilon greedy with epsilon=0
      class StaticBestBandit(Bandit):

          def __init__(self, data):

              super().__init__(data)


          def choose(self, context, gains, arm=None):
              """Choose action from context and history.

              If arm is None, then use strategy.
              Else, force choice of specified arm.
```

```
        """
        if arm is None:
            arm = np.argmax(self.mu)
        self.mu += gains
        return arm, gains[arm]


    def update(self, arm, context, gain):
#           self.mu[arm] += (self.s[arm] * self.mu[arm] + gain) / (self.s[arm] +␣
 ↪1)
#           self.s[arm] += 1
        self.cur += 1
```

[13]:
```
sb = StaticBestBandit(d)
sb.run()
plt.plot(sb.average_pseudo_regret())
plt.plot(sb.average_regret())
```

[13]:
```
[<matplotlib.lines.Line2D at 0x7f9d2d934990>]
```



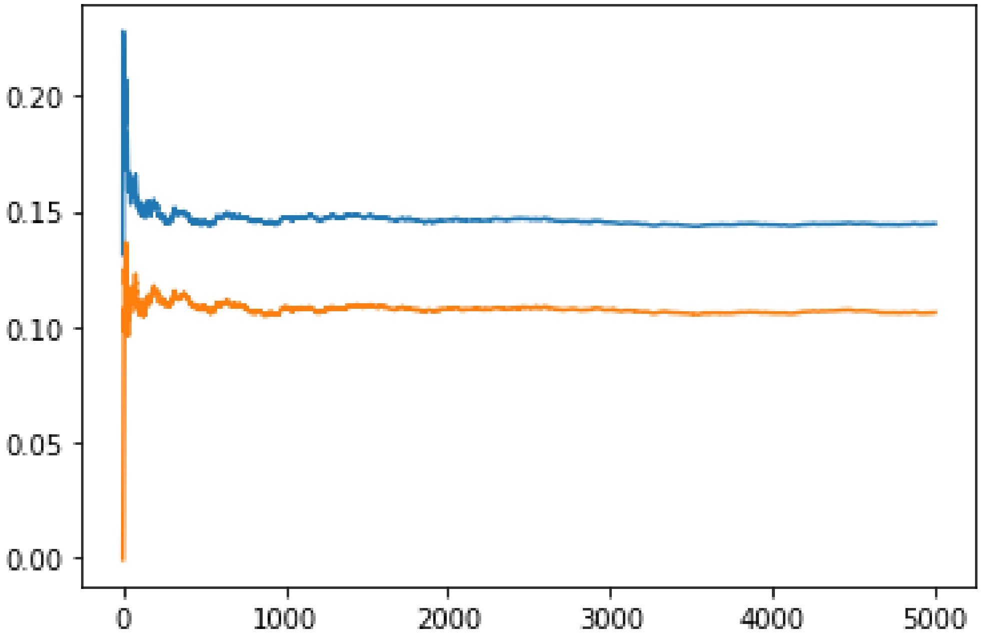
[14]:
```
class EpsGreedyBandit(Bandit):

    def __init__(self, data, eps):

        super().__init__(data)
        self.eps=np.clip(eps, 0, 1)


    def choose(self, context, gains, arm=None):
        """Explore with probability self.eps, else greedy.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        if arm is None:
            if np.random.rand() < self.eps: # explore
                arm = np.random.choice(self.arms)
            else:
                arm = np.argmax(self.mu / self.s) # exploit
        return arm, gains[arm]


    def update(self, arm, context, gain):
        self.mu[arm] += (self.s[arm] * self.mu[arm] + gain) / (self.s[arm] + 1)
        self.s[arm] += 1
        self.cur += 1
```

[15]:

```
eg = EpsGreedyBandit(d, 0.5)
eg.run()
plt.plot(eg.average_pseudo_regret())
plt.plot(eg.average_regret())
```

[15]:

```
[<matplotlib.lines.Line2D at 0x7f9d2d8a9950>]
```



[16]:

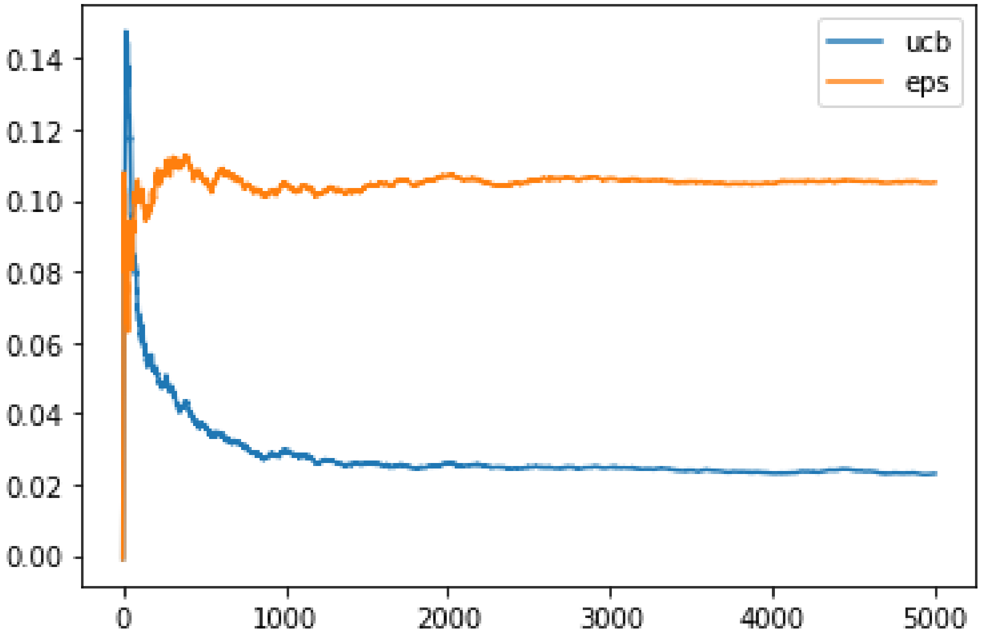
```
class UCBBandit(Bandit):

    def __init__(self, data):

        super().__init__(data)



    def choose(self, c, g, best, it, arm=None):
        if not arm:
            bound = self.mu / self.s + np.sqrt(2*np.log(it) / self.s)
            arm = np.argmax(bound)
        return arm, g[arm], best


    def choose(self, context, gains, arm=None):
        """Explore with probability self.eps, else greedy.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        if arm is None:
            bound = self.mu / self.s + np.sqrt(2*np.log(self.cur) / self.s)
            arm = np.argmax(bound)
        return arm, gains[arm]


    def update(self, arm, context, gain):
        self.mu[arm] += (self.s[arm] * self.mu[arm] + gain) / (self.s[arm] + 1)
        self.s[arm] += 1
        self.cur += 1
```

[17]:

```
ucb = UCBBandit(d)
ucb.run()
# plt.plot(ucb.pseudo_regret())
plt.plot(ucb.average_regret(), label="ucb")
eg = EpsGreedyBandit(d, 0.5)
eg.run()
# plt.plot(eg.pseudo_regret())
plt.plot(eg.average_regret(), label="eps")
plt.legend()
```

[17]:

```
<matplotlib.legend.Legend at 0x7f9d2d89ad50>
```



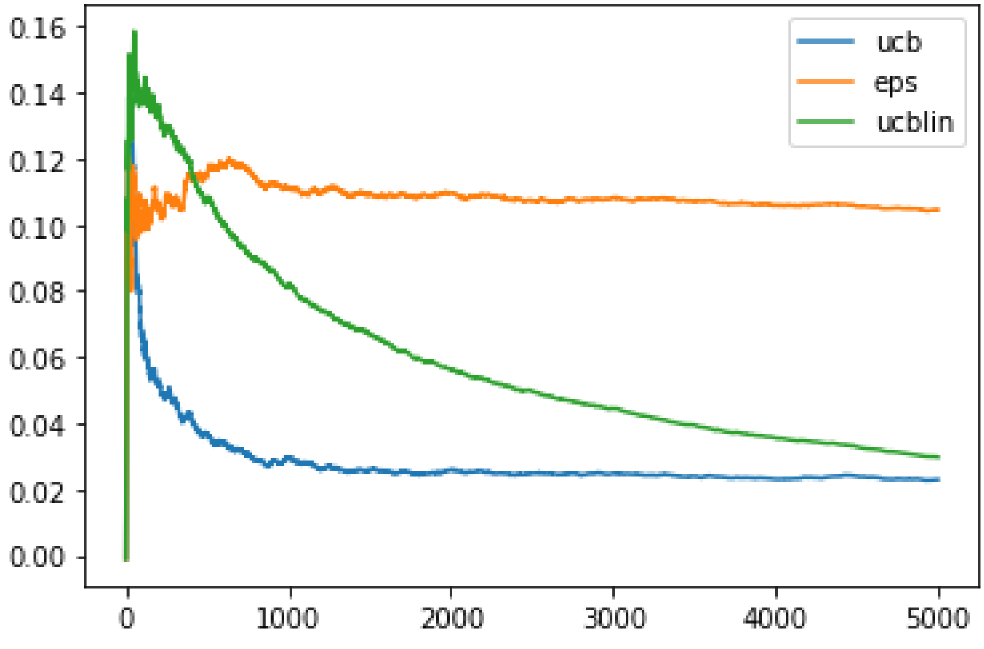
[18]:
```python
class UCBLinBandit(Bandit):

    def __init__(self, data, delta):

        super().__init__(data)

        self.A = np.zeros((self.N_arms, data.d, data.d))
        for arm in self.arms:
            self.A[arm] = np.eye(data.d)

        self.b = np.zeros((self.N_arms, data.d))

        self.delta = delta
        self.alpha = 1 + np.sqrt(np.log(2 / self.delta) / 2)


    def choose(self, context, gains, arm=None):
        """Explore with probability self.eps, else greedy.

        If arm is None, then use strategy.
        Else, force choice of specified arm.
        """
        if arm is None:
            p = np.zeros(self.arms.size)
            for arm in self.arms:
                A_inv = np.linalg.inv(self.A[arm])
                theta = A_inv.dot(self.b[arm])
                p[arm] = theta.dot(context) + self.alpha * np.sqrt(context.
↪dot(A_inv).dot(context))
            arm = np.argmax(p)
        return arm, gains[arm]


    def update(self, arm, context, gain):
        self.mu[arm] += (self.s[arm] * self.mu[arm] + gain) / (self.s[arm] + 1)
        self.s[arm] += 1
        self.cur += 1
        self.A[arm] = self.A[arm] + np.outer(context, context)
        self.b[arm] = self.b[arm] + gain * context
```

[19]:

```
ucbLin = UCBLinBandit(d, 0.5)
ucbLin.run()
ucb = UCBBandit(d)
ucb.run()
plt.plot(ucb.average_regret(), label="ucb")
eg = EpsGreedyBandit(d, 0.5)
eg.run()
plt.plot(eg.average_regret(), label="eps")
plt.plot(ucbLin.average_regret(), label="ucblin")
plt.legend()
```

[19]:

```
<matplotlib.legend.Legend at 0x7f9d2d8dd650>
```

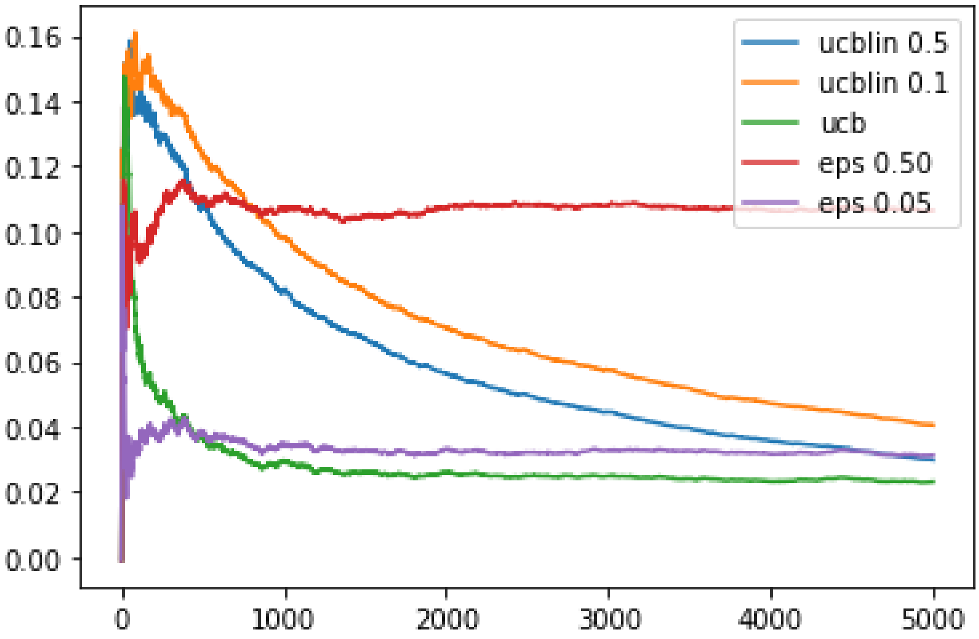


[20]:

```
eg05 = EpsGreedyBandit(d, 0.05)
eg05.run()
eg50 = EpsGreedyBandit(d, 0.5)
eg50.run()
ucb = UCBBandit(d)
ucb.run()
ucbLin50 = UCBLinBandit(d, 0.5)
ucbLin50.run()
ucbLin10 = UCBLinBandit(d, 0.1)
ucbLin10.run()

plt.plot(ucbLin50.average_regret(), label="ucblin 0.5")
plt.plot(ucbLin10.average_regret(), label="ucblin 0.1")
plt.plot(ucb.average_regret(), label="ucb")
plt.plot(eg50.average_regret(), label="eps 0.50")
plt.plot(eg05.average_regret(), label="eps 0.05")

plt.legend()
```

[20]:

```
<matplotlib.legend.Legend at 0x7f9d2d74ded0>
```

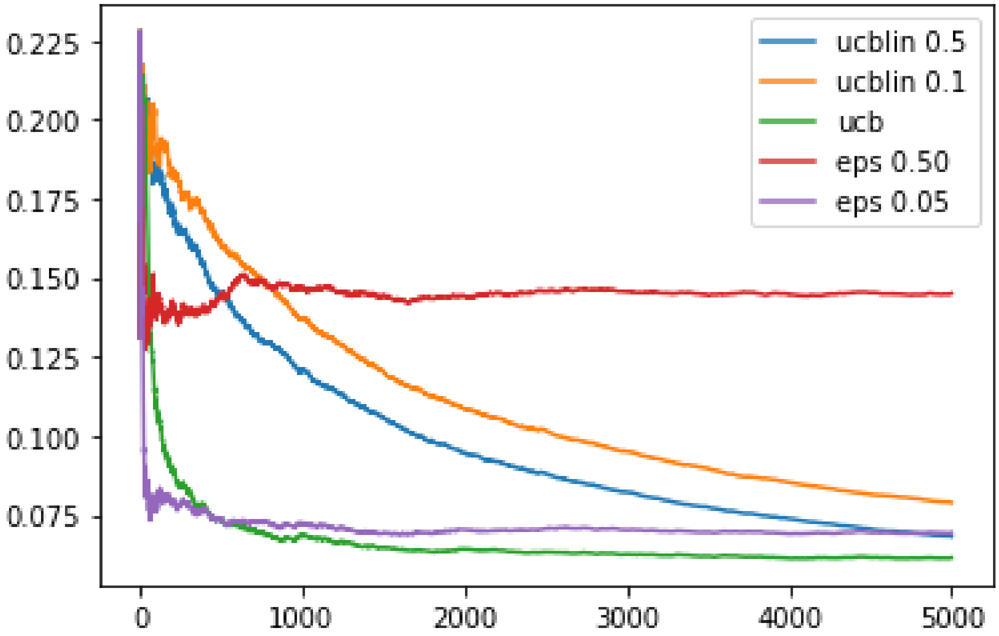


[21]:

```
eg05 = EpsGreedyBandit(d, 0.05)
eg05.run()
eg50 = EpsGreedyBandit(d, 0.5)
```

```
eg50.run()
ucb = UCBBandit(d)
ucb.run()
ucbLin50 = UCBLinBandit(d, 0.5)
ucbLin50.run()
ucbLin10 = UCBLinBandit(d, 0.1)
ucbLin10.run()

plt.plot(ucbLin50.average_pseudo_regret(), label="ucblin 0.5")
plt.plot(ucbLin10.average_pseudo_regret(), label="ucblin 0.1")
plt.plot(ucb.average_pseudo_regret(), label="ucb")
plt.plot(eg50.average_pseudo_regret(), label="eps 0.50")
plt.plot(eg05.average_pseudo_regret(), label="eps 0.05")

plt.legend()
```

```
[21]: <matplotlib.legend.Legend at 0x7f9d2d6d6c10>
```



3.1 Interpretation

We see that UCB, Epsilon greedy (0.05) and UCB Linear seem to attain the same asymptotic average regret (and pseudo-regret). UCB Linear is slower to converge than Linear: it is not as sample efficient with this dataset.