In [1]:
```
import ANN
import numpy as np
import copy
from pprint import pprint
from collections import defaultdict as ddict
```

In [2]:
```
numNeurons = 100
```

In [3]:
```
class hopfieldNetwork:
    def __init__(self, Input):
        self.Input = Input
        self.InputComplement = -1 * Input
        self.numNeurons = self.Input.shape[1]
        self.neuronList = [hopfieldNeuron(1,i) for i in range(self.numNeurons)]
        self.mapInputToNeurons(self.Input)
        self.connections = ddict(list)
        self.connect_neurons()
        self.compute()

    def mapInputToNeurons(self, Input):
        for index, neuron in enumerate(self.neuronList):
            neuron.input = Input[:,index]

    def connect_neurons(self):
        for i, neuron in enumerate(self.neuronList):
            for j, neuron_2 in enumerate(self.neuronList, i+1):
                self.connections[neuron].append((neuron_2, int(neuron.input*neuron_2.input)))
                self.connections[neuron_2].append((neuron, int(neuron.input*neuron_2.input)))

    def compute(self, mode ='async'):
        if mode == 'sync':
            new_output = []
            for neuron in self.connections:
                for neuron_in, weight in self.connections[neuron]:
                    neuron.localField += weight*neuron_in.input
                neuron.output = neuron.activation(neuron.localField)
                new_output.append(neuron.output)
                neuron.localField = 0

            new_output = np.array([new_output])
            self.mapInputToNeurons(new_output)
        elif mode == 'async':
            for neuron in self.connections:
                for neuron_in, weight in self.connections[neuron]:
                    neuron.localField += weight*neuron_in.input
                neuron.output = neuron.activation(neuron.localField)
                neuron.localField = 0
                neuron.input = neuron.output
            new_output = np.array([[i.output for i in self.neuronList]])
        return new_output

    def runHopfieldNetwork(self, test, count=25):
        hop.mapInputToNeurons(test)
        curr_state = test
        states = [curr_state]
        while not ((curr_state == self.Input).all() or
                   (curr_state == self.InputComplement).all() or
                   count == 0):
            curr_state = self.compute()
            states.append(curr_state)
            count -= 1
        return states

class hopfieldNeuron(ANN.neuron):
    def __init__(self, layer, index, activation_method='step'):
        self.input = []
        self.localField = 0
        self.activation_method= activation_method
```

In [4]:
```
a = np.array([[-1,1,1,1,-1,1,-1,1]])
```

In [5]:
```
hop = hopfieldNetwork(a)
```

In [6]:
```
pprint(hop.runHopfieldNetwork(np.array([[-1,-1,1,1,1,1,1,1]])))
```

```
[array([[-1, -1,  1,  1,  1,  1,  1,  1]]),
 array([[-1,  1,  1,  1, -1,  1, -1,  1]])]
```

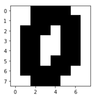
Memoricemos algunos digitos

In [7]:
```
from sklearn import datasets
import matplotlib.pyplot as plt
```

In [8]:
```
#Load the digits dataset
digits = datasets.load_digits()
```

In [9]:
```
# Binarize the dataset
for digit_im, digit_data in zip(digits['images'], digits['data']):
    digit_im[digit_im>0] = 1
    digit_data[digit_data>0] = 1
    digit_data[digit_data==0] = -1
```

In [10]:
```
#Display the first digit
plt.figure(1, figsize=(3, 3))
plt.imshow(digits.images[0], cmap=plt.cm.gray_r, interpolation='nearest')
plt.show()
```



In [11]:
```
hop = hopfieldNetwork(np.matrix(digits.data[0]))
```

In [12]:
```
print(digits.data[0])
```

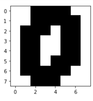
```
[-1. -1.  1.  1.  1. -1. -1. -1. -1.  1.  1.  1.  1. -1. -1.  1.
  1.  1. -1.  1. -1. -1. -1.  1.  1. -1. -1.  1.  1. -1. -1.  1. -1.
 -1.  1. -1. -1. -1.  1.  1. -1. -1.  1.  1. -1. -1.  1.  1. -1.  1.
 -1. -1. -1. -1.  1.  1. -1. -1. -1.]
```

In [13]:
```
print([i.output for i in hop.neuronList])
```

```
[-1, -1, 1, 1, 1, 1, -1, -1, -1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, 1, -1, 1, 1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, 1, -1, -1, 1, 3, -
1, 1, 1, -1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, -1, 1, 1, 1, 1, -1, -1, -1]
```

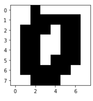
In [14]:
```
output = np.array([i.output for i in hop.neuronList])
image_out = output.reshape((8,8))
```

In [15]:
```
#Display the first digit
plt.figure(1, figsize=(3, 3))
plt.imshow(image_out, cmap=plt.cm.gray_r, interpolation='nearest')
plt.show()
```



In [16]:
```
output[3:6] = -1
image_out = output.reshape((8,8))
```

In [17]:
```
#Display the first digit
plt.figure(1, figsize=(3, 3))
plt.imshow(image_out, cmap=plt.cm.gray_r, interpolation='nearest')
plt.show()
```



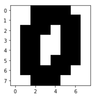
In [18]:
```
hop.mapInputToNeurons(np.matrix(output))
```

In [19]:
```
hop.compute()
```

Out[19]:
```
array([[-1, -1,  1,  1,  1,  1, -1, -1, -1, -1,  1,  1,  1,  1, -1,
        -1,  1,  1,  1, -1,  1,  1, -1, -1, -1,  1,  1, -1, -1,  1, -1,
        -1,  1,  1, -1, -1,  1,  1, -1, -1, -1,  1,  1, -1,  1,  1, -1,
        -1,  1,  1,  1,  1,  1, -1, -1, -1, -1,  1,  1,  1,  1, -1, -1]])
```

In [20]:
```
output = np.array([i.output for i in hop.neuronList])
image_out = output.reshape((8,8))
```

In [21]:
```
#Display the first digit
plt.figure(1, figsize=(3, 3))
plt.imshow(image_out, cmap=plt.cm.gray_r, interpolation='nearest')
plt.show()
```



In [22]:
```
a * -1
```

Out[22]:
```
array([[ 1, -1, -1, -1,  1, -1,  1, -1]])
```

Visualicemos algunos cambios de estado

In [23]:
```
start_image = np.matrix(digits.data[0])
perturb_image = copy.deepcopy(digits.data[0])
perturb_image[0:32] = -1


hop = hopfieldNetwork(start_image)
states = hop.runHopfieldNetwork( np.matrix(perturb_image))
pprint(states)

image_out = states[0].reshape(8,8)
```

```
[matrix([[-1, -1,  1,  1, -1, -1,  1, -1, -1, -1,  1,  1,  1,  1, -1, -1,
          -1, -1, -1, -1,  1, -1, -1, -1, -1, -1,  1,  1, -1, -1, -1, -1,
          -1,  1,  1, -1, -1,  1,  1, -1, -1, -1,  1,  1, -1,  1,  1, -1,
          -1,  1,  1,  1,  1,  1, -1, -1, -1, -1,  1,  1,  1,  1, -1, -1]]),
 array([[-1, -1,  1,  1, -1, -1,  1, -1, -1, -1,  1,  1,  1,  1, -1, -1,
         -1, -1,  1,  1, -1,  1,  1, -1, -1, -1,  1,  1, -1, -1, -1, -1,
         -1,  1,  1, -1, -1,  1,  1, -1, -1, -1,  1,  1, -1,  1,  1, -1,
         -1,  1,  1,  1,  1,  1, -1, -1, -1, -1,  1,  1,  1,  1, -1, -1]])]
```

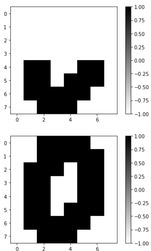
In [24]:
```
from IPython import display
plt.ion()

f, ax = plt.subplots(1,1)
im = ax.imshow(states[0].reshape(8,8), cmap=plt.cm.gray_r, interpolation = 'nearest')

f.colorbar(im)
f.canvas.draw()

for i in range(len(states)):
    try:
        im.set_data(states[i].reshape(8,8))
        f.canvas.draw()
        display.display(f)
        display.clear_output(wait=True)
        plt.pause(0.1)

    except KeyboardInterrupt:
        break
plt.ioff()
plt.close()
```



In [25]:
```
plt.ion()

f = plt.figure(1, figsize=(3, 3))
im = plt.imshow(start_image.reshape((8,8)), cmap=plt.cm.gray_r, interpolation='nearest')
plt.show()
```