Neural Information Processing 2018/2019

Course work #2: The different forms of learning in the brain

For this course work you are asked to implement and explore the behaviour of one classical supervised, reinforcement or unsupervised learning algorithm, and to discuss how they relate to learning in the brain. <u>You only need to select one of the topics below</u>. You can choose your language of preference, but we would recommend using Python or Matlab.

1. **Supervised: The backpropagation algorithm**
   The backpropagation algorithm is often used in machine learning to solve the credit assignment problem. Here you are going to contrast its different elements (e.g. error backpropagation, or symmetric weights) to how the brain is organised. You should use a simple feedforward neural network with one hidden layer and sigmoidal units to teach the network to compute logic gates (AND, OR *and* XOR). Optional: Test your network with the widely used handwritten digit recognition dataset (MNIST).

   You can use these papers as *references* when contrasting backprop with the brain:
   - Blake and Lillicrap, Dendritic solutions to the credit assignment problem, Current Opinion in Neurobiology 2018 (link)
   - Sacramento et al., Neural Information Processing Systems 2018 (link)

2. **Reinforcement: Temporal difference learning**
   Implement the basic TD learning algorithm to find a good path (given by a policy) for an agent exploring the environment from a starting point to a reward location in a simple environment form. You will use the classical gridworld formulation of reinforcement learning. Use the following grid structure (or variations):

	W	**W**	**W**	**W**	**W**		
	W	**E**			**W**		
		W			**W**	**W**	
		W					
S	**W**						

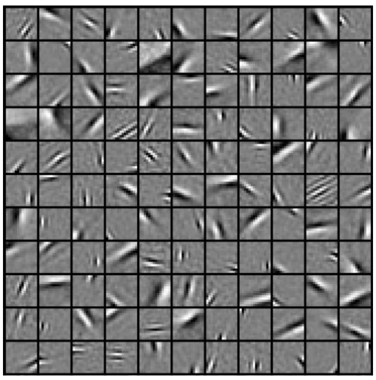
   Where **S** is the starting location and **E** the end location where reward is received. **W** represent walls, which can not be crossed over. The output of the algorithm should be its policy and the path that the agent should take, for example:

3	3	3	3	3	3	3	2
1	**W**	**W**	**W**	**W**	**W**	3	2
1	**W**	**E**	4	4	**W**	1	2
1	4	**W**	3	1	**W**	**W**	2
1	4	**W**	2	1	3	3	2
S	**W**	3	4	1	4	4	4

1 - Up; 2 - Down; 3 - Right; 4 - Left (these are the only possible actions)
You should also show the learning process of the algorithm.

References:
Sutton and Barto 1998/2018 (Chapter 6, available here);
W Schultz, P Dayan, PR Montague 1997 Science

3. **Unsupervised: Sparse coding**
Implement the classical sparse coding model of Olshausen and Field 1996 Nature for extracting features from natural images. Use the same natural images used in that paper available here. You should obtain receptive fields/weights similar to these ones:



References: Ko et al Nature 2011 (recent experimental paper demonstrating orientation/edge selectively in the visual cortex).

Questions

For the topic you have chosen you should implement the algorithm from scratch and address the following points:

1. How does the algorithm work? Plot the different components of the algorithm over learning to help you explain its behaviour (e.g. what are the weight changes given by backprop, how the policy/value function of TD-learning changes over learning, or/and plot the features/weights at different points during learning). You should also plot the performance (i.e. cost or value) of the algorithm over learning iterations (i.e. the learning curve). [max 300 words]

2. How does the algorithm relate to the brain? For example, which brain areas might implement it, and/or which neural circuits? Does it explain particular data observed in neuroscience? [max 500 words]

3. What are its key advantages over the other two learning algorithms/paradigms? [max 200 words]

4. What about disadvantages? And how could this be improved upon? [max 200 words]

Note 1: Where possible cite papers and/or use simulations/plots to support your claims.
Note 2: Collaborative work is encouraged (e.g. for coding and understanding of the algorithm), but every submission should be individual/unique.

Other relevant references:

- Doyak, Complementary roles of basal ganglia and cerebellum in learning and motor control. Curr Opin Neurobiol (2000) (link) [This review points out how different brain areas can be mapped onto *unsupervised learning*, *supervised learning* and *reinforcement learning*.]