CN540 Final Project

In this project, you will explore a computational model of visuo-motor reach adaptation based on Grosse-Wentrup and Vidal (2007). This model aims to explain how the brain learns to perform visually guided reaches by integrating both motor and visual sensory feedback via cortico-cerebellar-thalamo-cortical and cortico-striatal-thalamo-cortical loops. A typical visuo-motor adaptation experiment involves subjects reaching to target positions while wearing prism goggles. Since the prism goggles alter visual feedback, subjects must learn to adjust their reaches in order to accurately and quickly reach targets. As expected, initial reaches with the altered visual feedback are erratic and haphazard. However, training with the goggles gradually makes reaches closer to the straighter, slightly bowed reaching profiles seen with normal visual feedback (see Figure 4 in Gross-Wentrup and Vidal 2007).

The Grosse-Wentrup and Vidal model has three main components. The first component is based on the DIRECT model (Bullock et al. 1993), which provides a mechanism for learning sensory-motor transformations that allow reaching to a target. The DIRECT model learns to map coordinates given by the visual system in Cartesian space onto coordinates in joint rotation space, producing muscle activations that rotate the joints appropriately so that the hand reaches the target. Code (`cn540_striatum_model.m`) has been provided that implements the first component. The second component of the model is the cortico-cerebellar-thalamo-cortical loop. The cortico-cerebellar-thalamo-cortical loop learns to adjust the trajectory of the hand when the visual feedback information is wrong by a small amount. For example, if the eyes indicate the target is straight ahead, but the true target is actually one centimeter to the right, the cerebellar loop gradually learns to redirect the hand. Finally, the third component is the cortico-striatal-thalamo-cortical loop. This loop learns to adjust the trajectory of the hand when the visual feedback information is wrong by a large amount. In the Grosse-Wentrup and Vidal model, this initiates an adaptive search mechanism which probabilistically learns to choose the most likely direction of the target. Together, these last two components enable the model to learn to adjust for altered visual feedback.

For this project,

1) Show that you understand the DIRECT model by adding one additional joint to the model given in `cn540_striatum_model.m.` Produce code and explain in figures and words the effect of the additional joint.
2) Implement either the cortico-cerebellar-thalamo-cortical loop or the cortico-striatal-thalamo-cortical loop (HINT: the cortico-cerebellar-thalamo-cortical loop should be easier). Try to produce a figure like Figure 4 in Gross-Wentrup and Vidal 2007.
3) Criticize the model. What suggestions do you have for improving the model? Does the current model agree with what you have learned in class?

Hints for getting started:

See what the DIRECT model can do by typing

```
load('training_data.mat'); cn540_striatum_model(Z);
```

You can also specify the targets for reaching by typing

```
targets = [10, 30; -20, 40];  cn540_striatum_model(Z, targets);
```

The targets matrix can be any N x 2 matrix where the first coordinate is the x-position in Cartesian space and the second coordinate is the y-position in Cartesian space. Note that the targets matrix must always be the second argument i.e. `cn540_striatum_model(targets, Z);` will not work.

If you omit the Z and targets matrices, the DIRECT model will initiate a "babbling phase" where it learns how to reach to targets. This is how the matrix Z is produced. The babbling phase takes a long time, so I have provided an already trained matrix of weights in the file training_data.mat.

Finally, the code is heavily commented. You should go through the code carefully to understand how the DIRECT model works. This will help – especially in part two of the project.

References

Bullock, D., Grossberg, S., & Guenther, F. H. (1993). A self-organizing neural model of motor equivalent reaching and tool use by a multijoint arm. *Journal of Cognitive Neuroscience*, *5*(4), 408-435.

Grosse-Wentrup, M., & Contreras-Vidal, J. L. (2007). The role of the striatum in adaptation learning: a computational model. *Biological Cybernetics*, *96*(4), 377-388.