Regarding compass response functions for modeling path integration.

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Recently Haferlach, Wessnitzer, Mangan and Webb (2007) reported producing a novel neural model of the animal behaviour known as path integration, a navigation process requiring a compass and odometer. Here we comment on comparisons that that paper makes with our earlier work, (Vickerstaff & Di Paolo, 2005) where we also evolved a neural model of path integration.

The authors make prominent mention of the similarity of their compass sensors to the known properties of the polarisation-sensitive (POL) neurons found in insects. They give the impression that their compass response function, expressed as a dot-product equation (p. 274, eqn. 1, see below), has a closer similarity to POL neurons than does the cosine function we employed

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for our earlier model. In fact this is not the case. An examination of the equation shows that it simplifies to exactly the same function as the compass response function used in our paper:

$$\begin{bmatrix} \cos h_p \\ \sin h_p \end{bmatrix} \cdot \begin{bmatrix} \cos h_a \\ \sin h_a \end{bmatrix} = \cos h_p \cos h_a + \sin h_p \sin h_a = \cos(h_a - h_p)$$

where h_a is the agent's current heading and h_p is the preferred heading of the sensor. While this fact is known to the authors (J. Wessnitzer, personal communication, September 1, 2007), we felt it was not apparent from a reading of the paper alone.

This means that both models use shifted cosine functions as the compass response, whose values ranged from -1 to 1. As Haferlach et al. (2007) acknowledge in their discussion, POL neurons are not thought to have such a cosine response function when a dorsally presented polarised light stimulus is rotated through 360 degrees, rather they show roughly a cosine whose period is 180 degrees, and thus repeats itself over the full 360 degrees, leading to the problem of aliasing of directions separated by 180 degrees.

Consequently the only difference between their agent's sensory inputs and ours is that theirs (in their initial experiment) has three compass inputs with preferred directions of 60, 180 and 300 whereas ours has two compass inputs with preferred directions of 45 and 315 and an odometer (speed sensor).

The use of two compass inputs in Vickerstaff and Di Paolo (2005) was not motivated by neurophysiological data, but rather because it was clearly the simplest possible form of compass input available, and was selected since it was not known at the time whether evolving path integration in simulation was feasible. Our simulated task was also significantly harder, due to the presence of 70 per cent noise applied to the agent's forward speed, than that investigated by Haferlach et al., whose agent moves at constant speed and hence has no need of an odometric sensor.

While Haferlach et al. are justified in using a number of compass inputs that is larger than two, corresponding to the varied alignment directions found in the dorsal rim area (DRA) polarisation detectors possessed by insects, the compass response function they use is not an accurate reflection of POL neurons. Consequently, their modelling work has not yet produced a model of path integration using realistic compass inputs from a skylight compass.

Nor have they tackled the question of how a neural path integration system can use an odometer to accomodate variations in the animal's speed as it moves around. The simplest solution, as Haferlach et al. note, is to multiply the input from the compass sensors to the memory neurons storing the agent's home vector. But the standard CTRNN (Beer & Gallagher, 1992) model of neural dynamics they employ cannot perform multiplications in a straightforward way, and hence it will likely be difficult for such a network to evolve path integration for the case of variable speeds. This view is supported by our own failure to evolve a CTRNN path integration network when speed was a variable (Vickerstaff & Di Paolo, 2005). We solved this problem by augmenting the neural network equations to facilitate multiplication, and produced a compact and readily understandible solution which never-the-less uses a less realistic neuron model.

References

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