

Regarding Compass Response Functions For Modeling Path Integration: Comment on “Evolving a Neural Model of Insect Path Integration”

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Recently, Haferlach, Wessnitzer, Mangan, and Webb (2007) reported on the production of a novel neural model of the animal behavior known as path integration, a navigation process requiring a compass and an odometer. Here, we comment on comparisons that their 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 polarization-sensitive (POL) neurons found in insects. They give the impression that their compass response function, expressed as a dot-product equation (Haferlach et al., 2007, p. 274, equation 1; see below), has a closer similarity to POL neurons than does the cosine function we employed 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:

$$\begin{bmatrix} \cosh_p \\ \sinh_p \end{bmatrix} \begin{bmatrix} \cosh_a \\ \sinh_a \end{bmatrix} \\ = \cosh_p \cosh_a + \sinh_p \sinh_a = \cos(h_a - h_p).$$

Here, 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 polarized light stimulus is rotated through 360° . Rather, they show roughly a cosine whose period is 180° , and thus repeats itself over the full 360° , leading to the problem of aliasing of directions separated by 180° .

Consequently, the only difference between their agent's sensory inputs and ours is that their agent (in their initial experiment) has three compass inputs with preferred directions of 60 , 180 , and 300 , whereas our agent 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. Also, it was selected because it was not known at the time whether evolving path integration in simulation was feasible. Our simulated task was also significantly more difficult, because of 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 more than two compass inputs, corresponding to the varied

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alignment directions found in the dorsal rim area (DRA) polarization detectors possessed by insects, the compass response function they use is not an accurate reflection of POL neurons. Consequently, their modeling 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 accommodate 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. However, the standard continuous-time recurrent neural network (CTRNN; Beer & Gallagher, 1992) model of neural dynamics they employ cannot perform multiplications in a straightforward way. Thus, 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 understandable solution, which nevertheless uses a less realistic neuron model.

References

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