Does Optic Flow Explain the Firing of Grid Cells?

Florian Raudies (fraudies@bu.edu), Ennio Mingolla, and Michael Hasselmo

Problem. Various cues such as vestibular, sensorimotor, or visual information can lead to the firing of grid cells recorded in entorhinal cortex of rats. A recent model uses boundary vector cells to provide information about the 2D spatial position (Barry et al., *Review Neuroscience*, **17**, 2006). However, boundary vector cells need to know the angle and distance of the boundary wall. In contrast we study the estimation of 2D velocity and change of heading of the rat from optic flow and if this information can lead to grid cell firing.
Approach. A simple circular cage is modeled as a 3D world and trajectories of a rat's movement are simulated. Optic flow for a spherical camera model is calculated for regularly sampled locations on the ground of the cage. This flow information is used in a template model to estimate the rat's 2D linear velocity and yaw rotational velocity. 2D linear velocities are integrated into the velocity controlled oscillator (VCO) model (Burgess, *Hippocampus*, **18**, 2008) while spatial locations are taken from the original trajectory.
Result and Conclusion. If velocity estimates are temporally integrated over ~20min the error summation by path integration prevents generation of a clear grid cell firing pattern by the VCO model. However, for short durations velocity estimates and path integration are accurate. If we assume a reset mechanism that recalibrates the spatial location of the rat grid cell firing can be achieved. Different reset intervals were simulated and the grid score for the firing pattern was calculated. For a reset interval longer than one minute this grid score decreases rapidly. We conclude that grid cell firing is not generated only by optic flow, but that a recalibration of the spatial position using cues other than optic flow occurs at least every minute.
Supported by CELEST (NSF SMA-0835976).

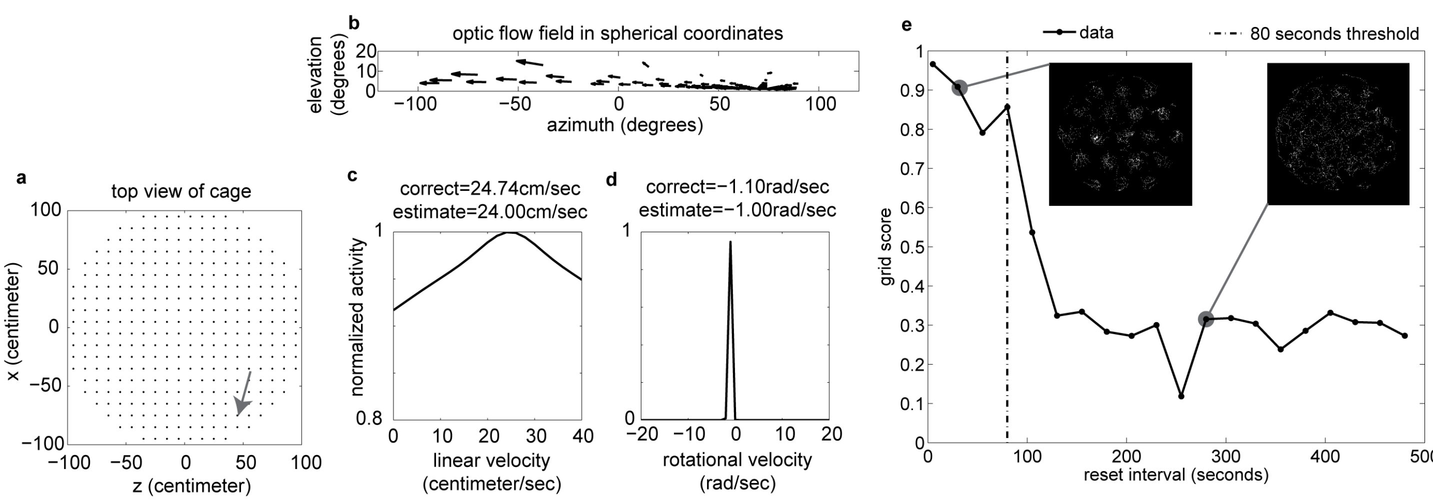

Figure legend. Stages of model function while a simulated rat moves along a recorded trajectory (Hafting et al. *Nature*, **436**, 2005; Trial 2) in a round cage. **(a)** Top view of the cage. The small gray arrow shows the position and orientation of the rat at time 2sec in a 20 minute session. **(b)** Optic flow field in spherical coordinates for the motion which occurs at the same moment as depicted in (a). Note that the flow appears upside down as it is projected to the back of the sphere. **(c,d)** Estimates of linear and rotational (d) velocity from the template model are shown. Note, that velocities are sampled at 2cm/sec and rotational velocities at 1rad/sec. In this case the model's estimates based on flow information is a sample value closest to the ground-truth. **(e)** Velocity estimates and orientation are integrated into the VCO model, which generates a spike pattern. For this spike pattern the grid score is calculated. The graph shows the grid score for different reset intervals ranging from 30sec to 480sec. At reset intervals above 80 sec (indicated by the dash dotted line) the grid score decreases drastically.