GRIDBOT: SPIKE-BASED HEAD DIRECTION CELLS EMPLOYING BAYESIAN INFERENCE

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INTRODUCTION

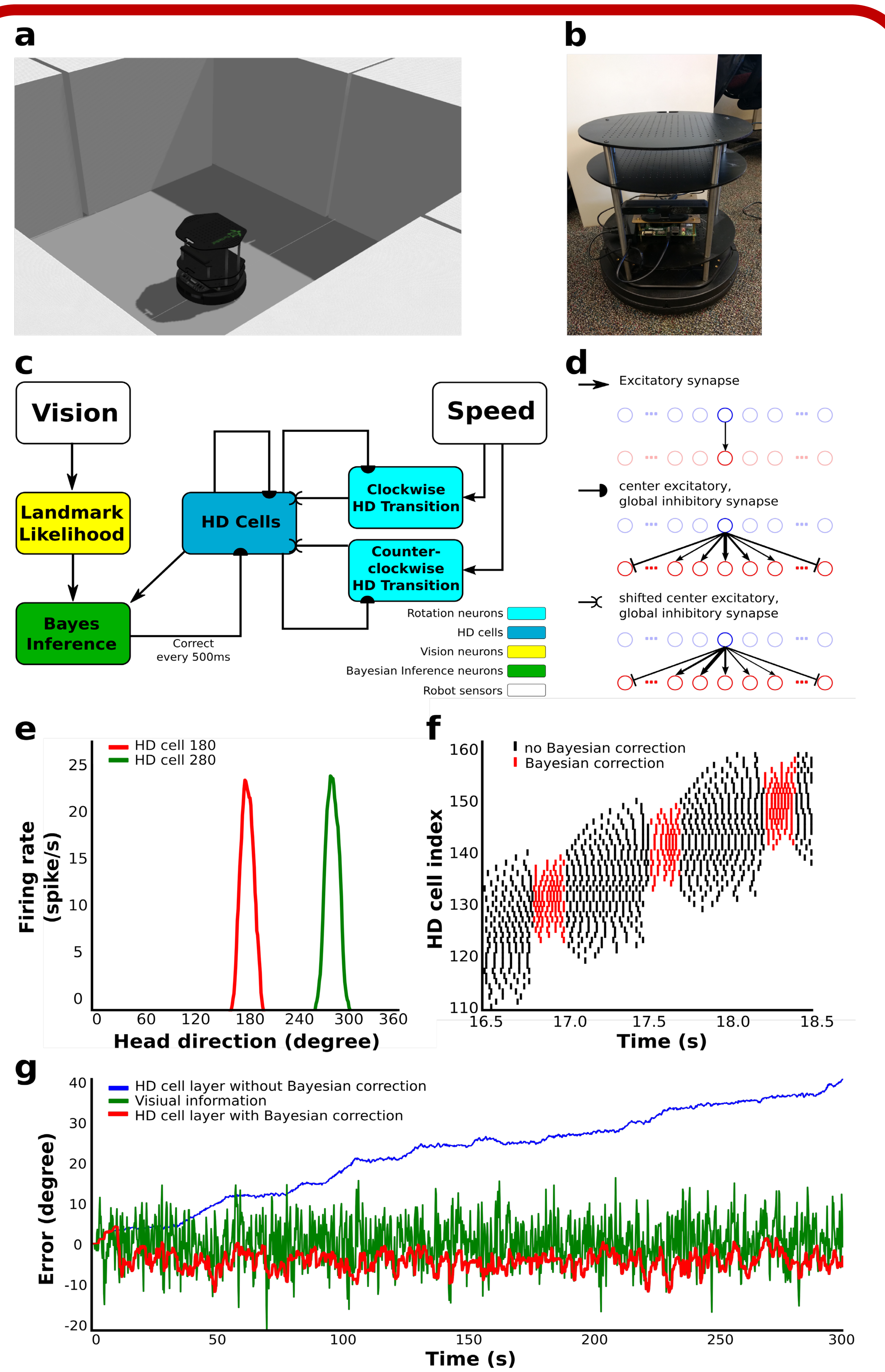
Localization and mapping have long been at the forefront of mobile robotic research. In the real world, the main challenge is to produce accurate estimates from noisy signals by overcoming errors due to hardware constraints and highly varying environmental conditions. Interestingly, localization and mapping are "effortless" and accurate functions for most mammalian brains. In the lab, we are developing the Gridbot, a neuro-mimetic robotic system that follows a "bottom-up" approach to self-orient autonomously and on real-time. Here, we present the first steps towards our goal, namely a head direction cell (HDC) layer, which provides an accurate representation of the robot direction using neural spikes.

MODEL

We developed our model in the Robot Operating System (ROS) environment to control a Turtlebot 2 (Fig. a and b). Each layer of our model was a node in ROS, and different layers communicated with each other using topics with customized spiking or current messages. The neurons were simulated using the leaky Integrate-and-Fire (LIF) model. For the HDC layer, we used 360 LIF neurons to allow for a directional resolution of 1 degree. Neuron membrane voltages were updated using the Euler method every 10 ms. The Bayesian Inference layer sampled both inputs over time, and drove strongly the HDC layer every 500 ms to correct it . We also assume that the visual information error at each time step is independent.

CONCLUSION

We showed that a model of an HDC system, reinforced by a neural layer that performs Bayesian filtering, can combine stimulus from a self-motion speed sensor and a visual sensor to accurately assess on the direction of the head. The addition of the visual information improved the head direction representation in the presence of noise. Although still its infancy, our robotic system mimics the behavioral abilities observed in mammals, at least in terms of localizing its head direction.



a) Gazebo simulator showing Turtlebot 2 in a custom-built environment.
b) The Turtlebot 2 robot with a depth camera attached to it.
c) The proposed neuro-mimicking HDC model that combines external (visual) and internal (speed sensor) information to estimate the head direction.
d) The three different types of synaptic connectivity used between layers.
e) The spike-based tuning curves of 2 neurons that are sensitive to a head direction of 180 and 280 degrees, respectively.
f) Applying Bayesian correction on the HDC network results to decreased neurons that fire.
g) Correcting for the error drift through the Bayesian Inference layer. The robot rotates with angular velocity of 10 deg/s (the simulated visual input error followed an independent Gaussian distribution).