A Neural Path Integration Mechanism for Adaptive Vector Navigation in Autonomous Robots

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Animals have evolved diverse navigational strategies in order to survive in complex dynamic environments. Path integration (PI) is one of these strategies, which enables them to integrate angular and linear ego-motion cues to maintain a vector representation of their current location with respect to the starting point, called home vector. It has been observed in many animals ranging from arthropods to mammals. Especially social insects, such as ants and bees, exhibit astonishing capabilities in PI as part of their central place foraging [7]. PI plays a crucial role in acquiring spatial knowledge by providing a metric. In recent years, many neural models of PI have been proposed [3], [6]. However only few of them have been applied on an actual physical robot [2], [4] and even fewer have discussed how PI mechanisms can be integrated in a neural architecture for complex navigation [1].

We present a neural PI mechanism interacting with neural locomotion control for homing behavior and associative goal learning in an autonomous hexapod walking robot. The mechanism is fed by inputs from an allothetic compass and an odometer. The home vector is computed and represented in circular arrays of neurons where heading angles are population-coded and linear displacements are rate-coded. Incoming signals are sustained through leaky neural integrator circuits and compute the home vector by local excitation-lateral inhibition interactions. An actor-critic reinforcement learning control [5] uses the computed home vector for state space exploration and associative learning of rewarding goal locations.

Using the angular difference between the heading and the home vector as feedback error for steering, we show that the PI mechanism can guide the robot back to its home position (see

Fig. 1). Furthermore, vector representations of goals can be successfully learned by combining reward- and correlation-based learning methods [5].

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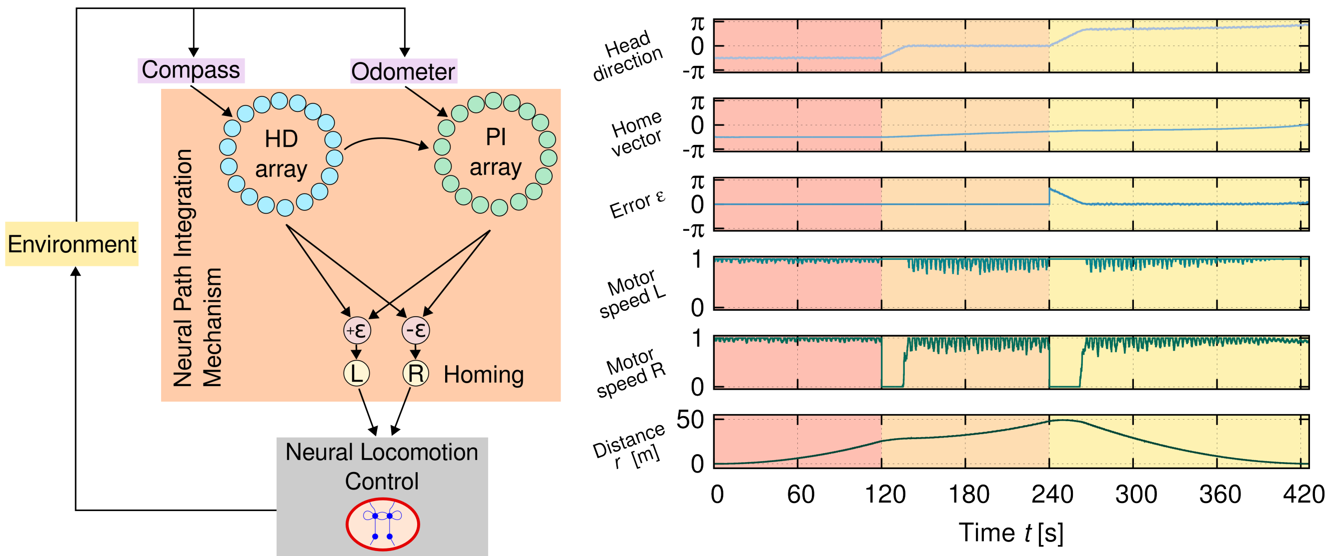

Fig. 1. (Left) A neural path integration mechanism interacting with neural locomotion control. (Right) Signals for homing behavior of a simulated walking robot using path integration. See supplementary video at http://www.manoonpong/BCCN2014/homing.wmv.