A cortical model for spatial navigation planning

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According to experimental evidence, spatial navigation planning is likely to rely upon a distributed neural network spanning limbic and cortical brain structures. This network includes *(i)* the hippocampus, which mediates robust spatial representations, and *(ii)* neocortical structures, such as the prefrontal cortex, which participate to the elaboration of more abstract contextual descriptions (e.g., accounting for motivation-dependent memories and action cost/risk constraints). In order to investigate this working hypothesis, we model the interaction between the hippocampus [1] and the prefrontal cortex [2]. We focus on the cortical columnar organisation to study a neuromimetic architecture suitable for spatial navigation planning. We validate the system's learning performance on a classical spatial behavioural task, the Tolman & Honzik's *detour* protocol [3], which suggests that rodents can plan flexible goal-directed trajectories in the presence of blocked pathways. We also put forth a set of statistical analysis to assess the spatial coding properties of the model hippocampal place and cortical column cells.

Here, we couple our hippocampal place cell [1] and columnar cortical [2] models to provide a better understanding of the dynamics of the action planning neural network. We also improve the biological plausibility of the cortical model, by explicitly identifying the subpopulations of (rate code) neurones that encode different information (e.g., current spatial state, goal-related and prospective memory signals, local actions). This approach has several advantages: *(i)* the response of each subpopulation being more specific, it makes it possible to perform a series of analyses of multiple neural activity correlates; *(ii)* the functioning of the columnar assembly can be formalised within the reinforcement learning framework, which proved to be relevant to the understanding of goal-related neural activities [4]; *(iii)* the biological plausibility of the model being enhanced, the discharges of formal units can be compared against experimental data (e.g., electrophysiological recordings [5,6]), and give rise to testable predictions.

The spatial planning model reproduces the experimental results by Tolman & Honzik [3]. It also unravels the possible links between the single unit level and the behavioural level relevant to the learning of the task (e.g., to the selection of the shortest path to the reward, and to the prediction of future state sequences). Finally, our neural response analysis suggests how the interplay between the model hippocampus and the prefrontal cortex can yield to the encoding of manifold information pertinent to the spatial planning function (e.g., prospective and distance-to-goal correlates).

Acknowledgements
Granted by EC Project ICEA (Integrating Cognition, Emotion and Autonomy), IST-027819-IP.

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