**Towards a real-world capable computational cognitive model of spatial memory**

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Computational cognitive models of spatial memory often neglect difficulties posed by the real world, such as sensory noise, uncertainty, and high spatial complexity. However, since cognition and its neural bases have been shaped by the structure and challenges of the physical world, cognitive models should take these into account as well.

In this work, we have taken an interdisciplinary approach towards developing a cognitively plausible spatial memory model able to function in real-world environments, despite the sensory noise and high spatial complexity. We investigated how spatially relevant brain areas might maintain an accurate location estimate of mammals, despite accumulating sensory noise, hypothesizing that hippocampal place cells might perform Bayesian cue integration. We provided single-neuron recording evidence for this claim from freely moving rats in several environments (acquired outside this PhD), and proposed a possible mechanism facilitating this statistically near-optimal information integration.

We also investigated spatial memory structure based on human behaviour data, not only strengthening prior claims that ‘cognitive maps’ consist of local sub-maps, as opposed to being unitary and global, but also proposing a computational mechanism (clustering in psychological space) which might give rise to these sub-map structures. Such structured, hierarchical spatial representations help to deal with large amounts of complex spatial information by increasing the speed and efficiency of retrieval search and of route planning, as well as facilitating economical storage. We validated our proposed mechanism using spatial memories of human subjects in over a hundred cities world-wide, and implemented a computational model able to predict, in advance, their sub-map structures based on our hypothesis.

Based on these insights, we developed a spatial memory module for a general cognitive architecture (the LIDA model of cognition), integrating it with the other cognitive mechanisms built into LIDA. We demonstrated the ability of the resulting model to deal with the challenges of the real world by running it in simulated environments, modelled after our participants’ actual urban environments, using high-fidelity robotic simulation software (including a physics engine) which provides the same interfaces as a real robot. Our LIDA-based spatial memory model could localize accurately, and could closely reproduce the spatial memory structures as well as planning times and efficiencies of human participants, substantiating the plausibility of the computational implementation of our hypotheses.

**Publications to be included in the alternative format thesis:**

* Madl T, Franklin S, Chen K, Montaldi D & Trappl R, *in preparation*. **Towards real-world capable spatial memory and navigation ability in the LIDA cognitive architecture**. *Biologically Inspired Cognitive Architectures*.
* Madl T, Franklin S, Chen K, Trappl R & Montaldi D, *submitted*. **Exploring the structure of spatial representations**. *Cognition*.
* Madl T, Chen K, Montaldi D & Trappl R, 2015. **Computational cognitive models of spatial memory in navigation space: A review**. *Neural Networks, 65, 18-43.*
* Madl T, Franklin S, Chen K, Montaldi D & Trappl R, 2014. **Bayesian Integration of Information in Hippocampal Place Cells.** *PLoS ONE 9(3), e89762*