Robustness of a model of the insects' celestial compass in realistic conditions

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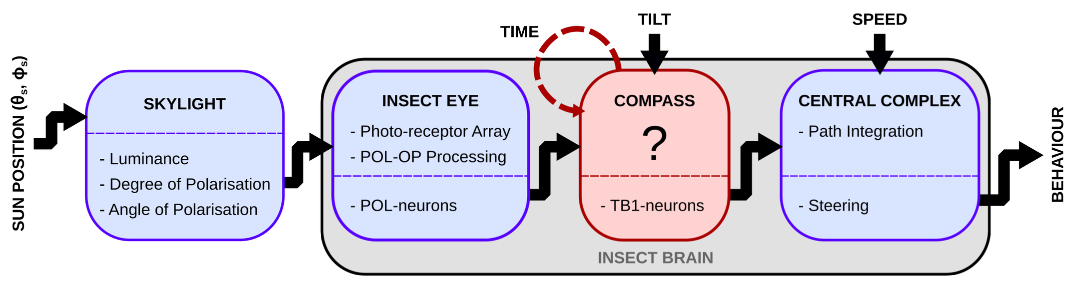
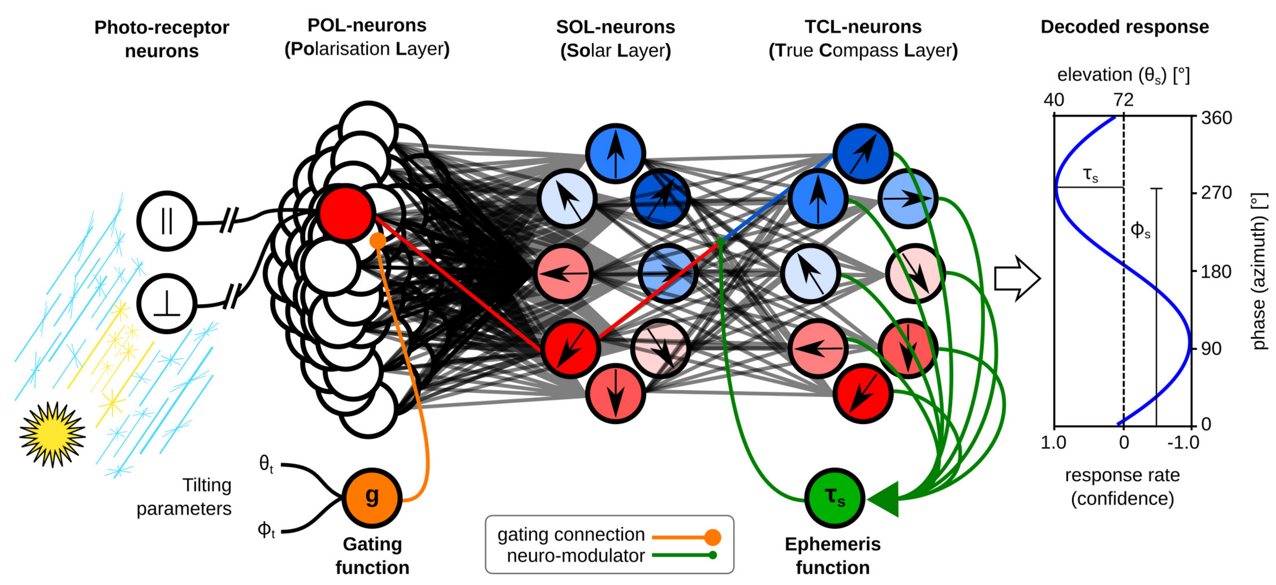
Introduction

Insects navigate by integrating the distance and direction travelled on an outward path using a **neural compass** based on external **celestial cues**.



We test the robustness of our computational model of this compass [1] for navigation in **adverse conditions** with sky disturbances.

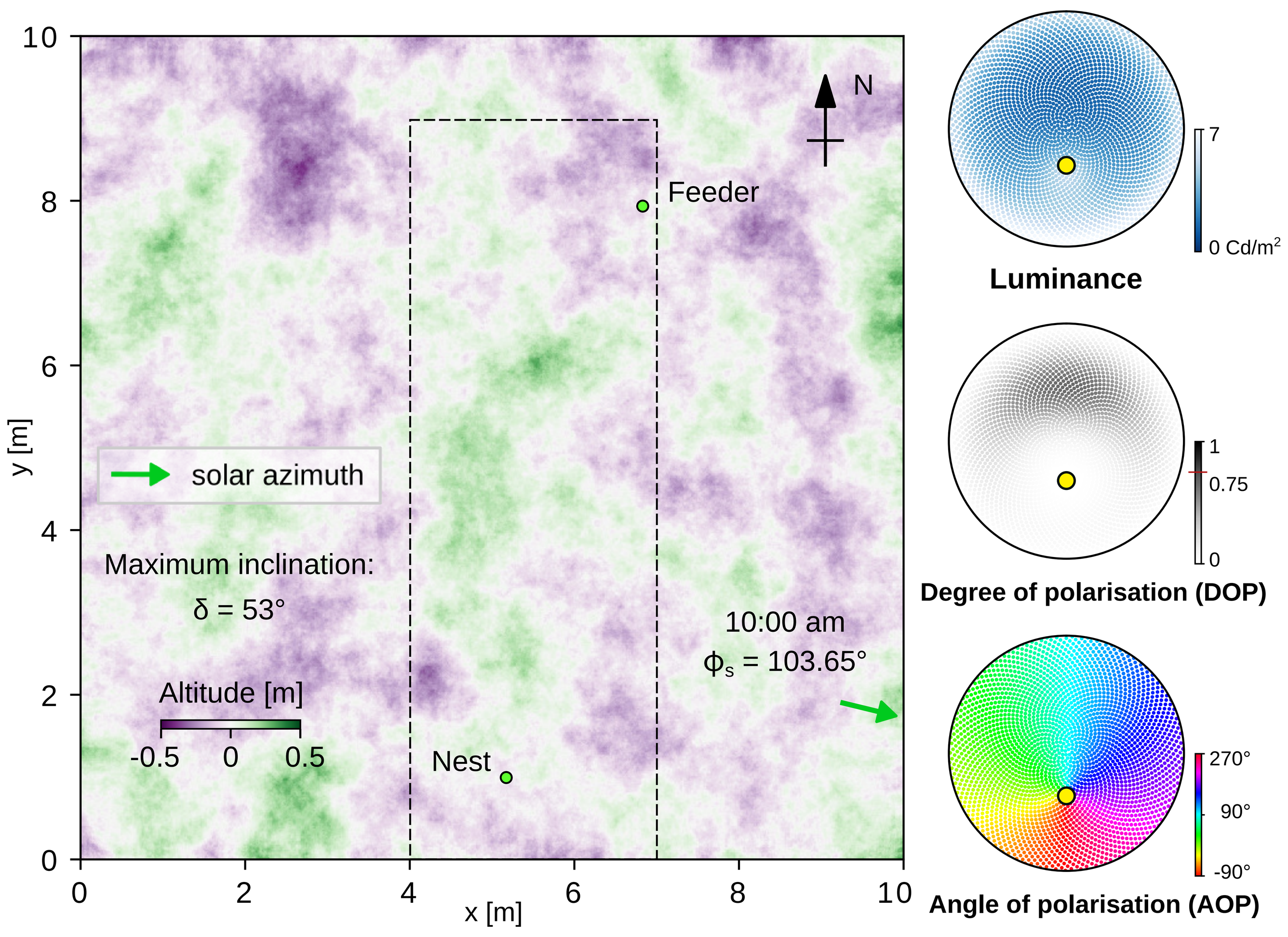
Computational compass model



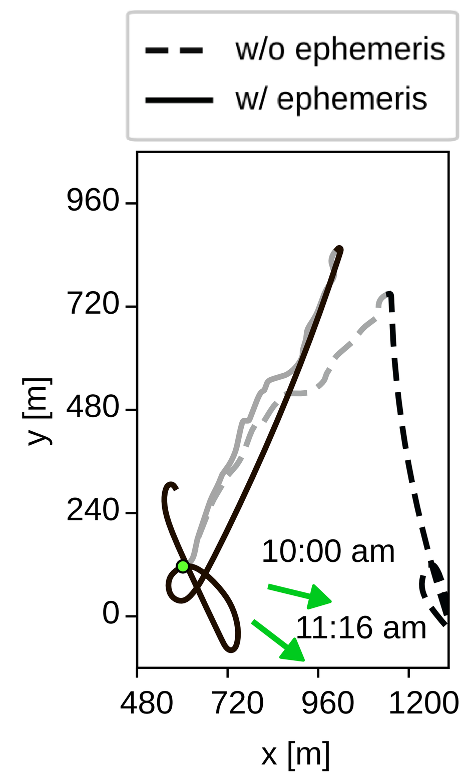
- microvilli filter polarised light before it stimulates the **opponent photo-receptors**
- **POL-neurons** integrate the signal from the opponent photo-receptors
- Hypothesis: **SOL-neurons** correct for head tilt and encode the sun direction
- Hypothesis: **TCL-neurons** correct for passing time and encode the global orientation

Methods: simulating realistic conditions

- An uneven terrain with 1 meter altitude variance is used introduce **head tilt**
- Previously recorded paths from desert ants were used as **outward** routes
- An agent was forced to follow an 'outward' route to the 'feeder', while **integrating its path** using our central complex (CX) model [2] with the **heading direction** from our celestial compass model [1]
- The agent steers itself to return to the starting point ('nest') creating an 'inward route'

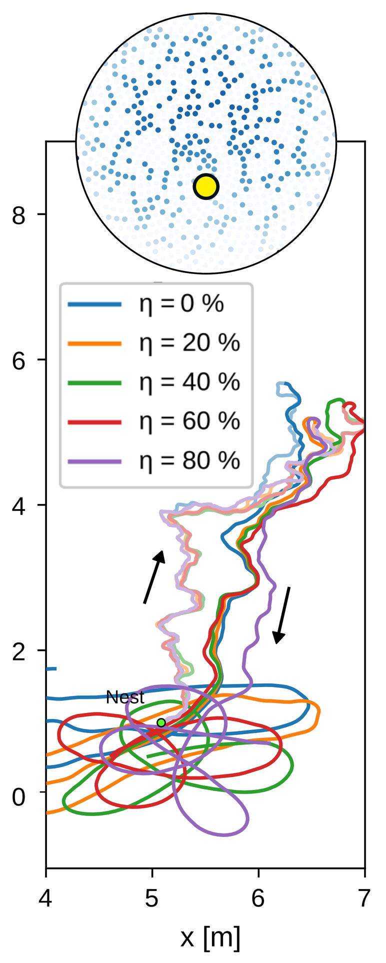


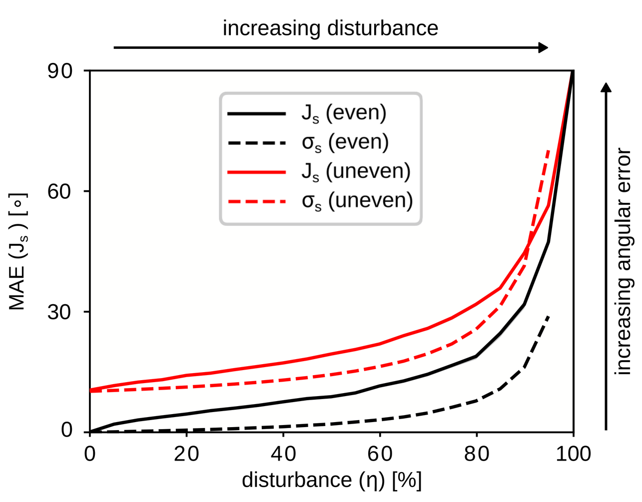
Long runs



- The compass was also tested while navigating for **long distances** corresponding to more than **an hour** of travel
- The sun moves $\sim 15°/\text{h}$
- Tested with and without the ephemeris mechanism for **time compensation**
- Although the angular error (J_s) is high, path integration is not affected much

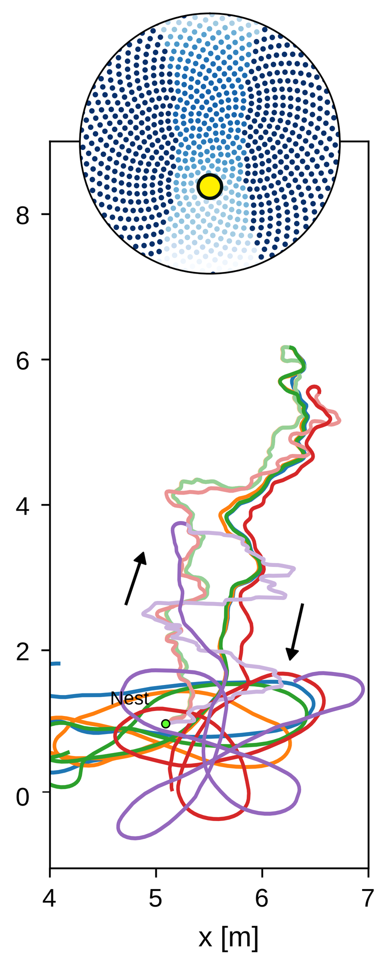
Uniform sky disturbance

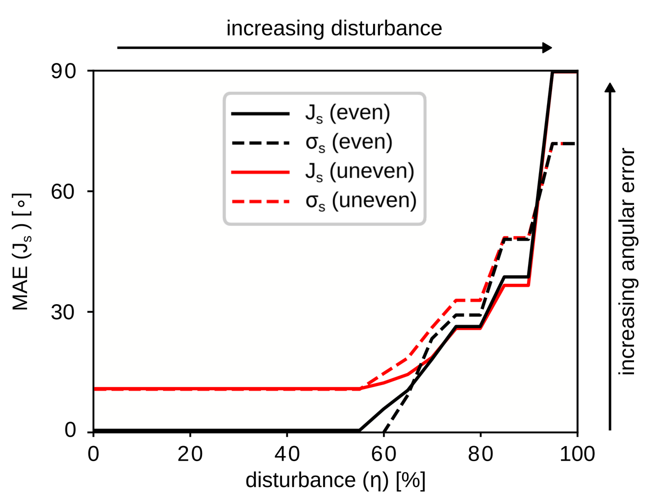




- Randomly set the polarisation in a percentage of the sky (η) to zero
- Simulates **uniform clouds** or **faulty photo-receptors**

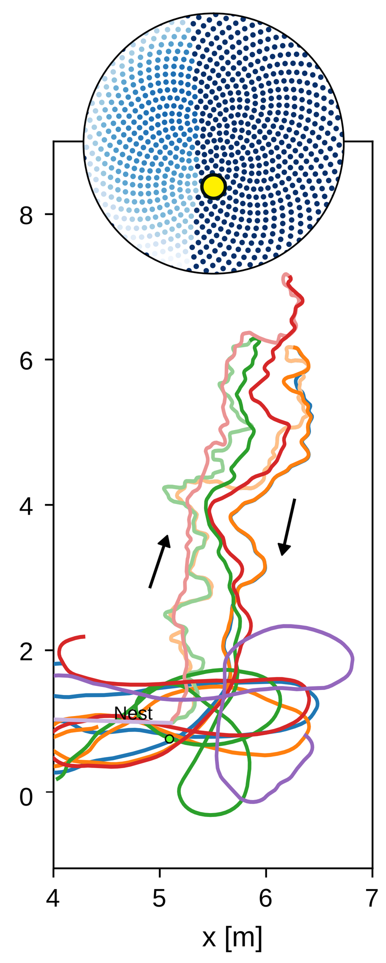
Corridor-like sky disturbance

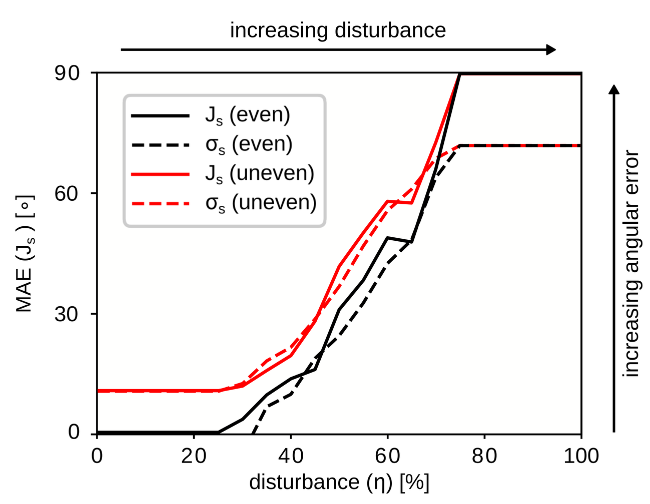




- Block a percentage of the sky (η) from both sides
- Simulates navigating in corridors, e.g. in between high vegetation

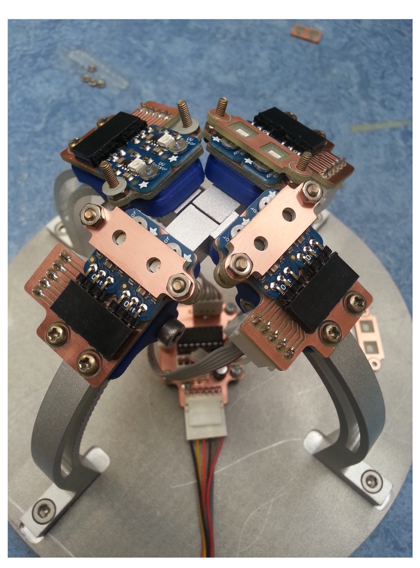
Canopy-like sky disturbance





- Block a percentage of the sky (η) from the one side
- Simulates navigating close to **canopies**, e.g. buildings, fences or trees

Future work



- Physical implementation of the compass model
- Test on a robot navigating under the real sky
- Integrate multiple celestial compasses, e.g. based on skylight polarisation, intensity, sun, etc.

Acknowledgements

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[1] E. Gkanias, B. Risse, M. Mangan, and B. Webb, ''From skylight input to behavioural output: a computational model of the insect polarised light compass,'' *PLoS Computational Biology*, vol. 15, no. 7, p. e1007123, 2019.

[2] T. Stone, B. Webb, A. Adden, N. B. Weddig, A. Honkanen, R. Templin, W. Wcislo, L. Scimeca, E. Warrant, and S. Heinze, ''An Anatomically Constrained Model for Path Integration in the Bee Brain,'' *Current Biology*, vol. 27, no. 20, pp. 3069—-3085.e11, 2017.