A bio-inspired celestial compass for a hexapod walking robot in outdoor environment

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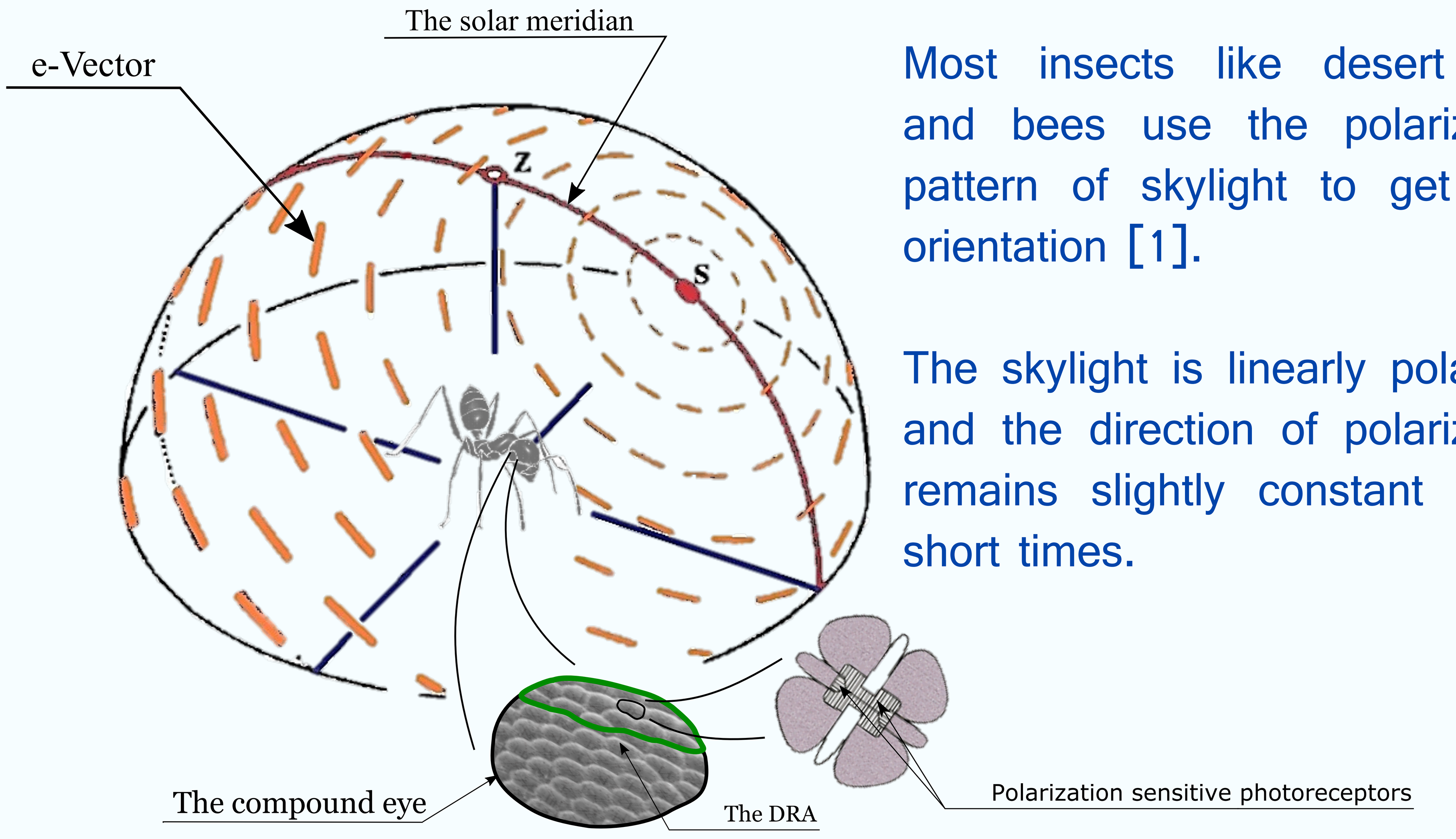
Aix-Marseille Université, CNRS, ISM, Biorobotics Team, Marseille, France

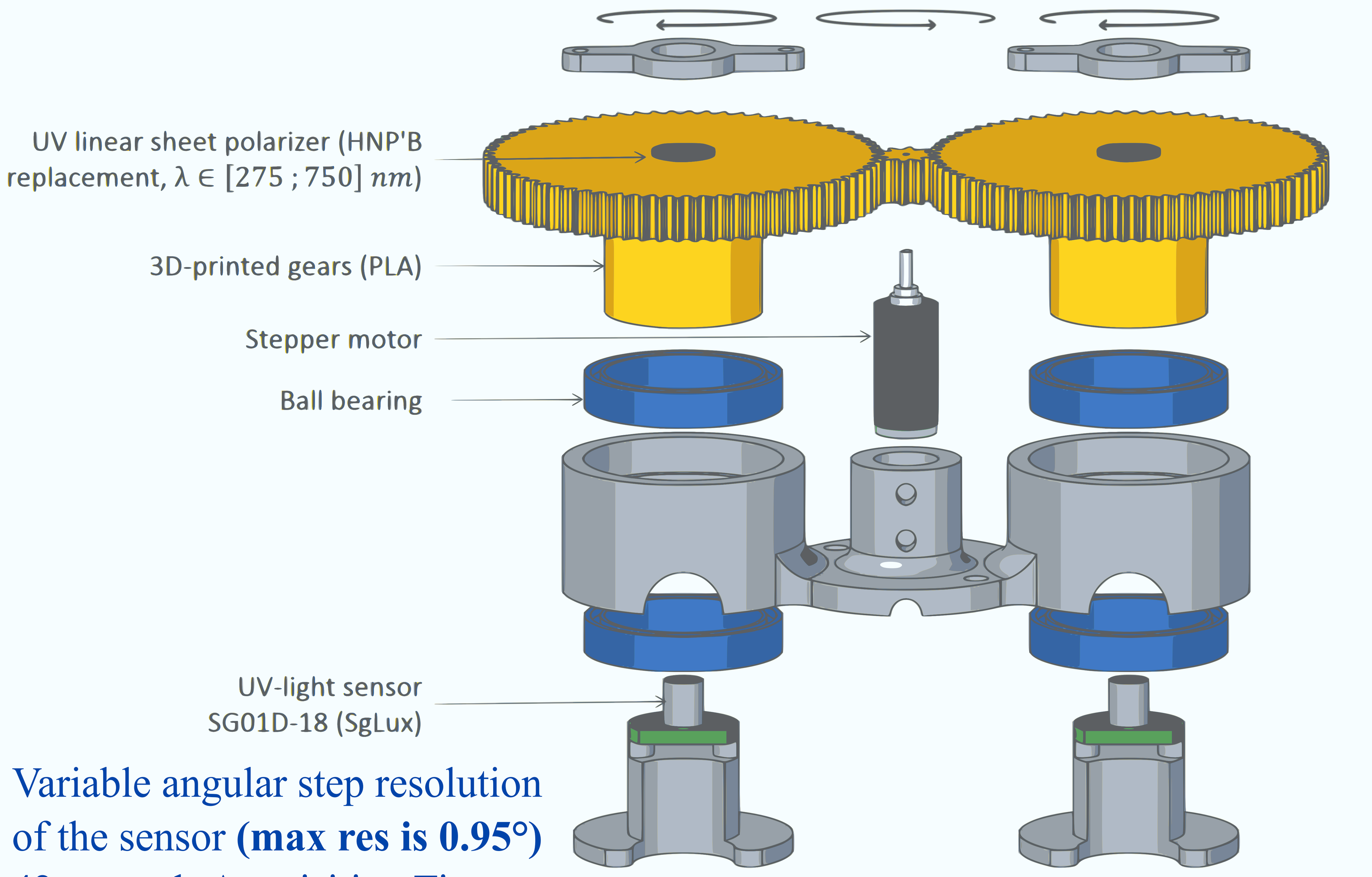
The polarized light detection in insects



Most insects like desert ants and bees use the polarization pattern of skylight to get their orientation [1].

The skylight is linearly polarized and the direction of polarization remains slightly constant within short times.

The celestial compass



Variable angular step resolution of the sensor (**max res is 0.95°**)
42-seconds Acquisition Time

The signal processing unit

The POL-sensor raw responses depending on the gear rotation angle x in [0, 2 π]:

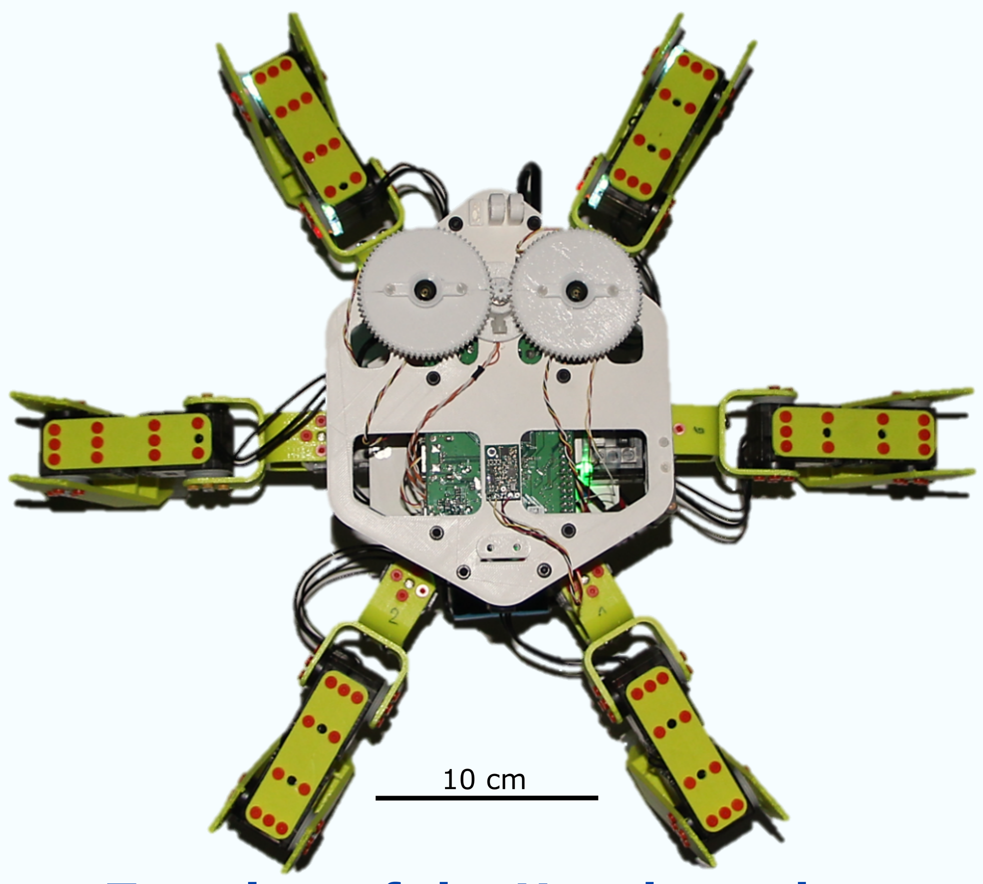
$$\begin{cases} UV_0(x) = A_0 + B_0 \cdot cos(2(x+\psi)) \\ UV_1(x) = A_1 + B_1 \cdot cos(2(x+\psi+\frac{\pi}{2})) \end{cases}$$

where ψ is the solar meridian direction angle in $[0,\pi]$. We then define p(x) as the log ratio of both normalized and corrected UV_0 and UV_1 POL-signals:

$$p(x) = log_{10}\left(\frac{UV_1^{nc}(x)}{UV_0^{nc}(x)}\right)$$

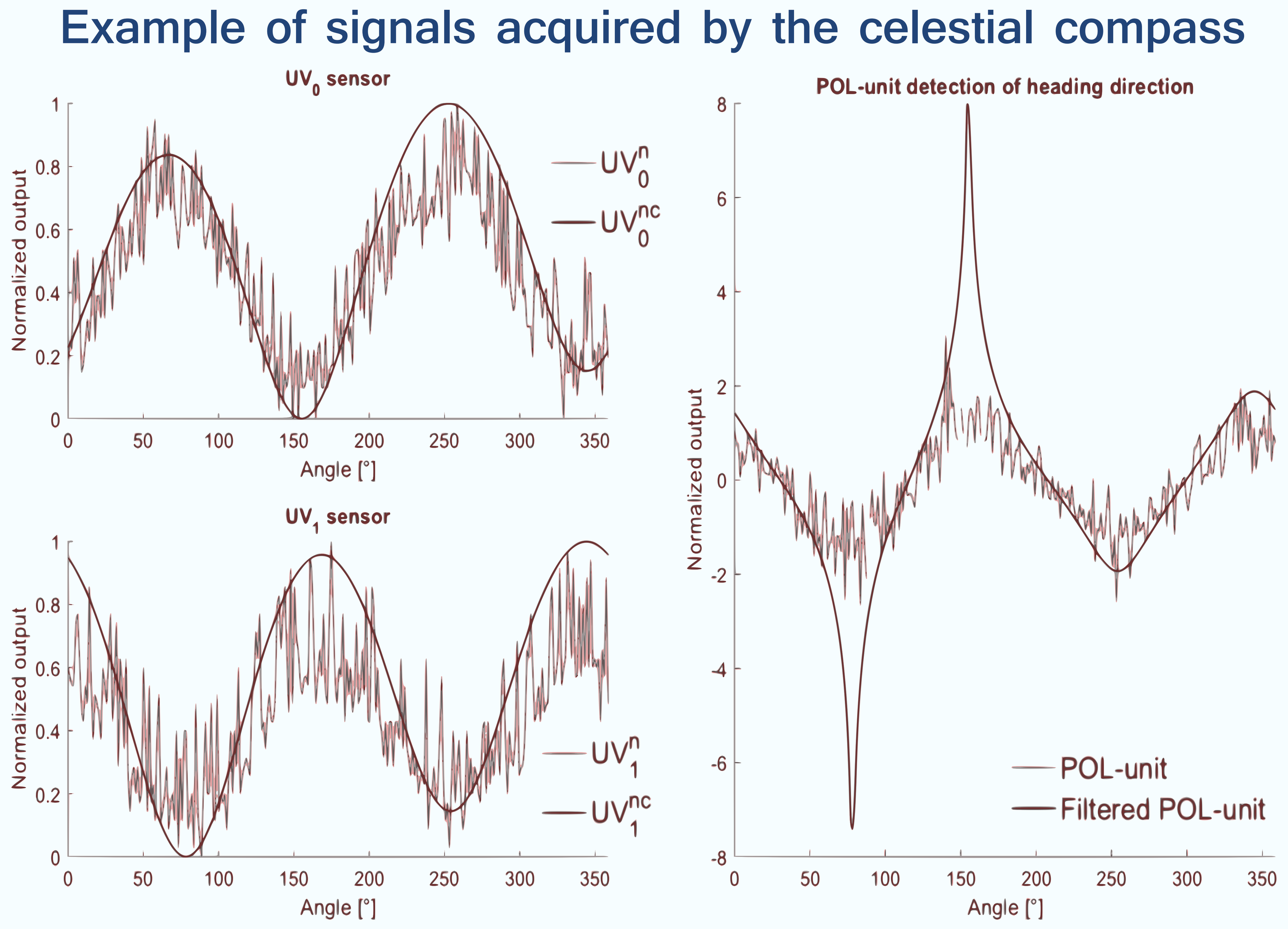
Finally, ψ is computed as follows:

$$\psi = \frac{1}{2}\left(\underset{x\in[0;\pi]}{\arg\min}\, p(x) + \underset{x\in[\pi;2\pi]}{\arg\min}\, p(x) - \pi\right)$$

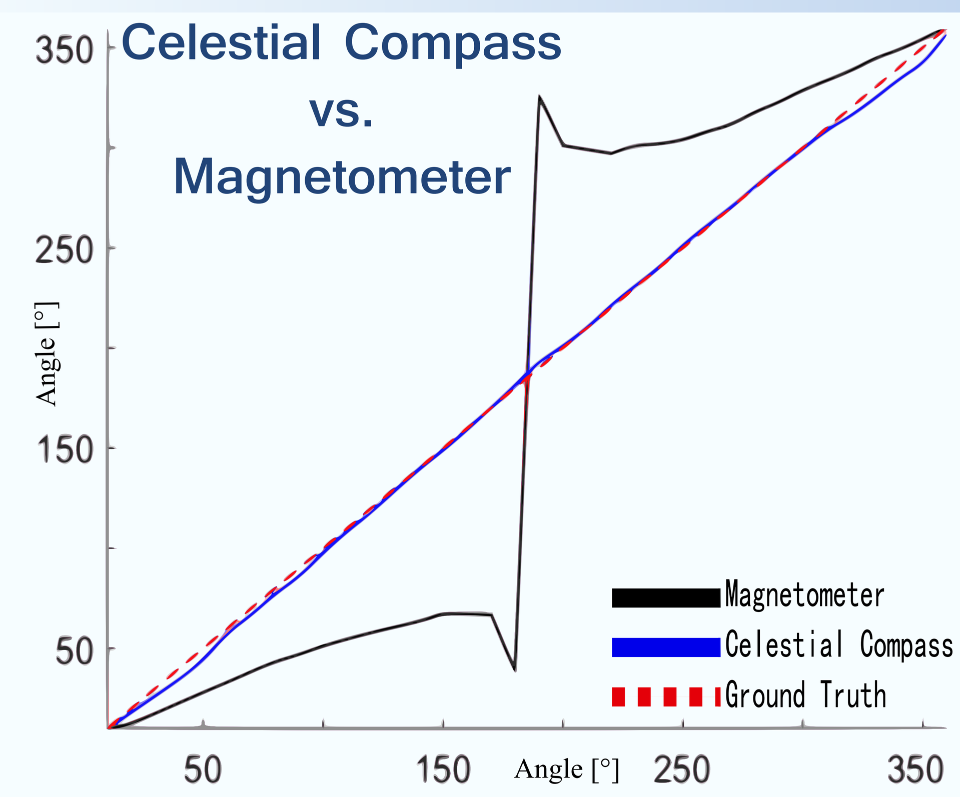


Top view of the Hexabot robot equipped with the UV-polarized light compass [2].

Example of signals acquired by the celestial compass



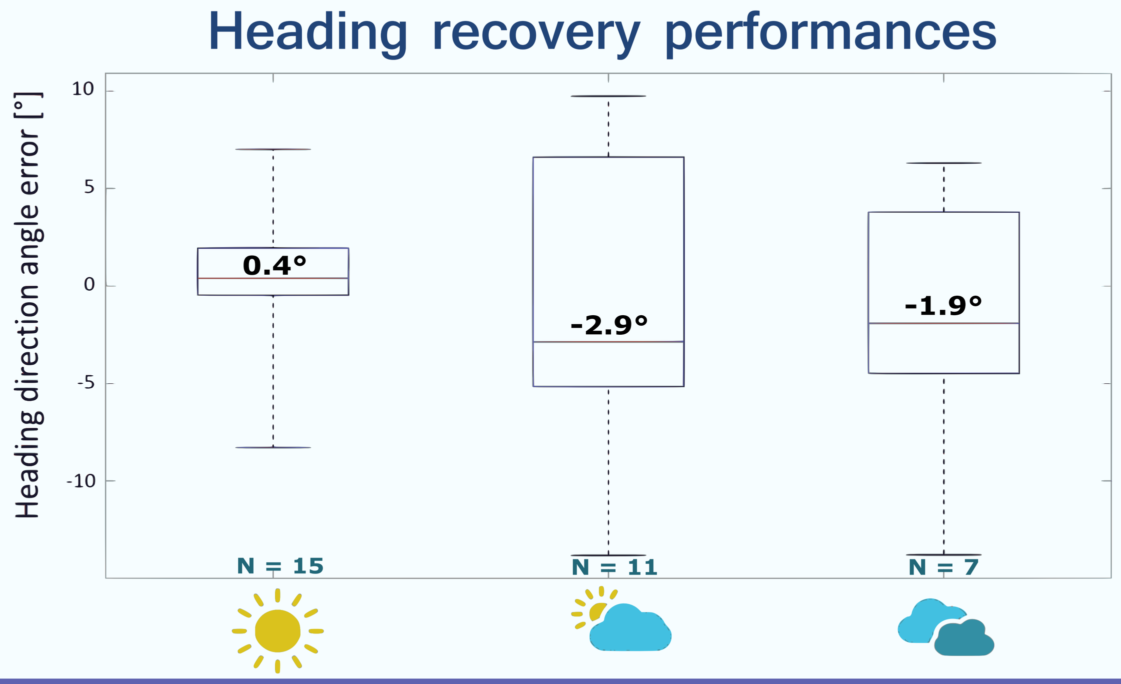
Results



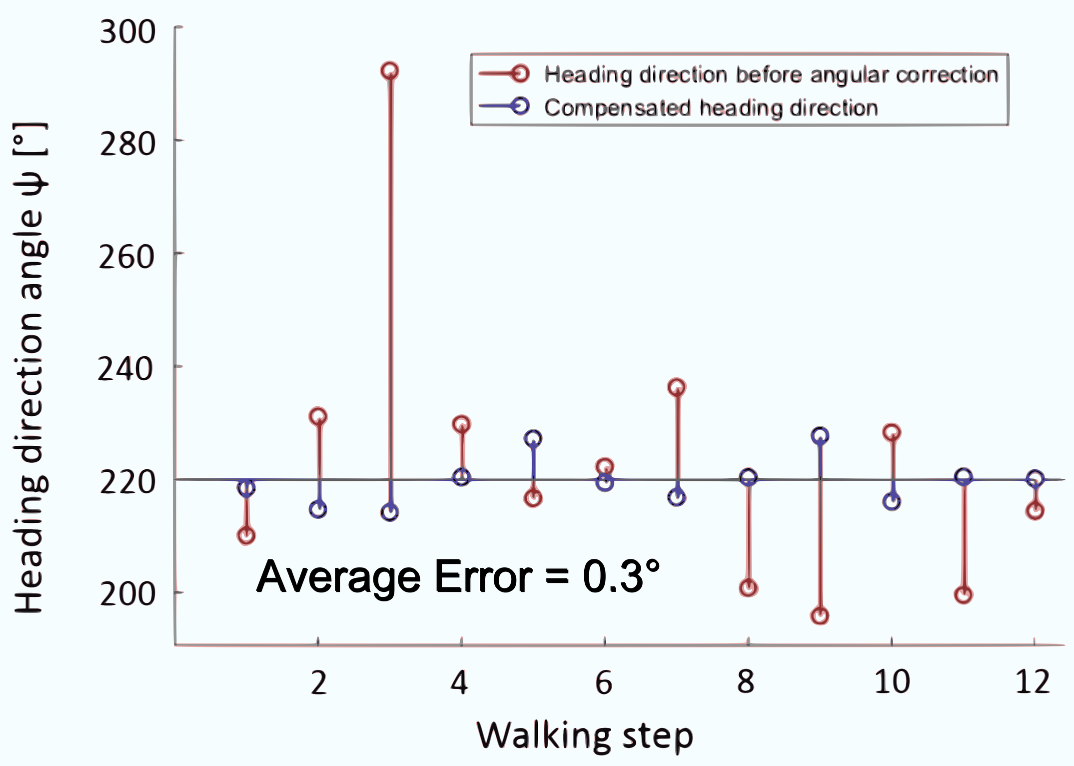
Performances of the celestial compass under various weather conditions [3]

Conditions	UV_{P-P}	Cv	n
Clear Sky, UV-index = 1	365	6%	42
Overcast Sky, UV-index = 1	102	22%	30
Clear Sky, UV-index = 7	1048	5%	72
Overcast Sky, UV-index = 7	144	19.5%	72

Heading recovery performances



Heading lock over a straight-forward walking task



Conclusion

Heading direction error from 0.3° to 2.9° under various weather conditions: **High Reliability**.

Sensory modalities very similar to those of insects : **robotic insect embodiment.**

Even under poor weather conditions, these results highlights **good precision** to make the optical compass **suitable for field robotics.**

References

[1] T. Labhart. Polarization-opponent interneurons in the insect visual system. Nature, vol. 331, no 6155, pp. 435-437, 1988.
[2] J. Dupeyroux, G. Passault, F. Ruffier, S. Viollet, J. Serres. Hexabot: a small 3D printed six-legged walking robot designed for ant-like navigation tasks. 20th IFAC World Congress, Toulouse, France, pp. 16628-16631, 2017.
[3] J. Dupeyroux, J. Diperi, M. Boyron, S. Viollet, J. Serres. A bio-inspired celestial compass applied to an ant-inspired robot for autonomous navigation. Mobile Robots (ECMR), 2017 European Conference on. IEEE, 2017.

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Julien Dupeyroux
PhD Student at the Biorobotics Department
Institute of Movement Sciences