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Julien Dupeyroux, Julien Diperi, Marc Boyron, Stéphane Viollet, Julien Serres. A bio-inspired celestial compass for a hexapod walking robot in outdoor environment. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2017), Sep 2017, Vancouver, Canada. hal-01643182

**HAL Id: hal-01643182**
**https://amu.hal.science/hal-01643182**

Submitted on 21 Nov 2017

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


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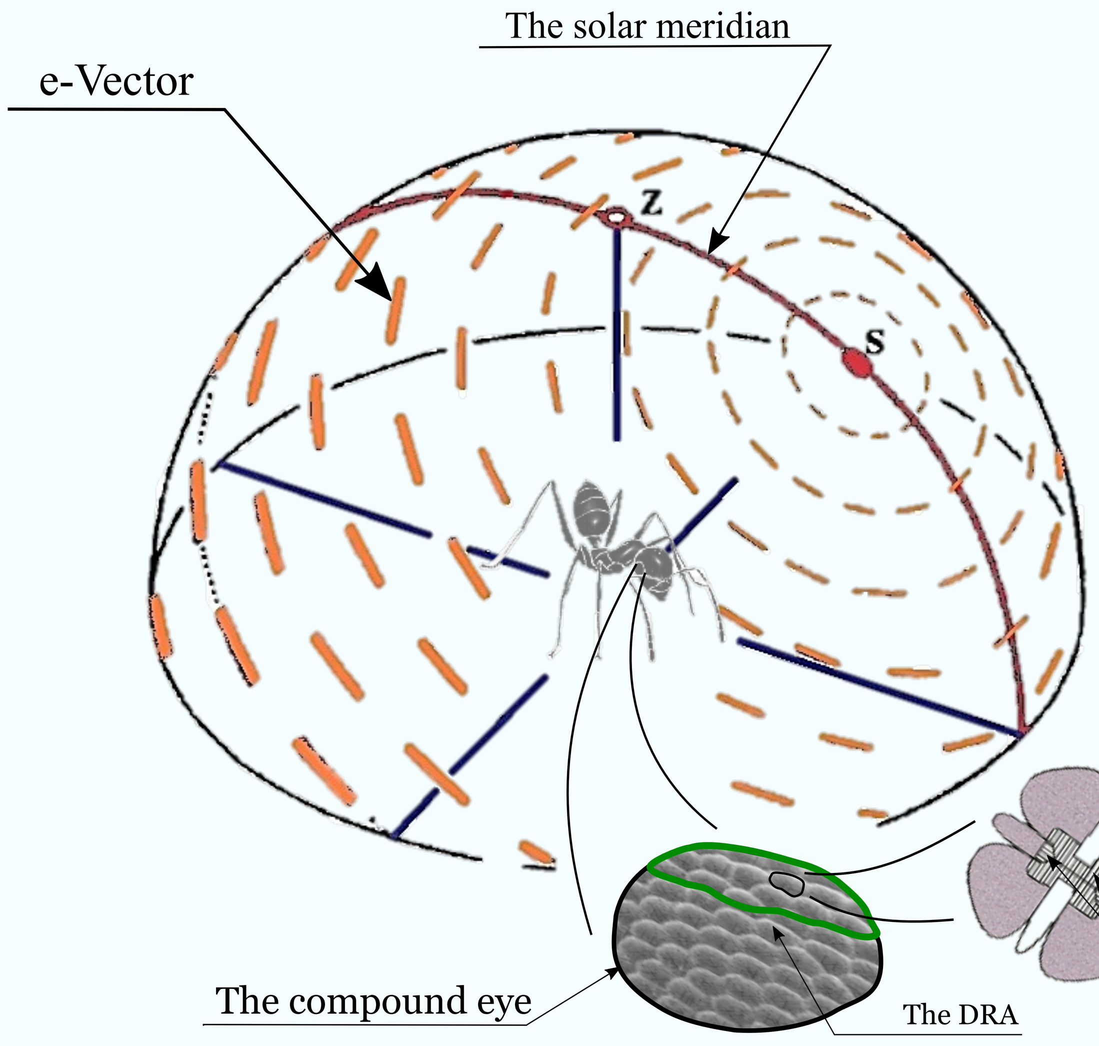
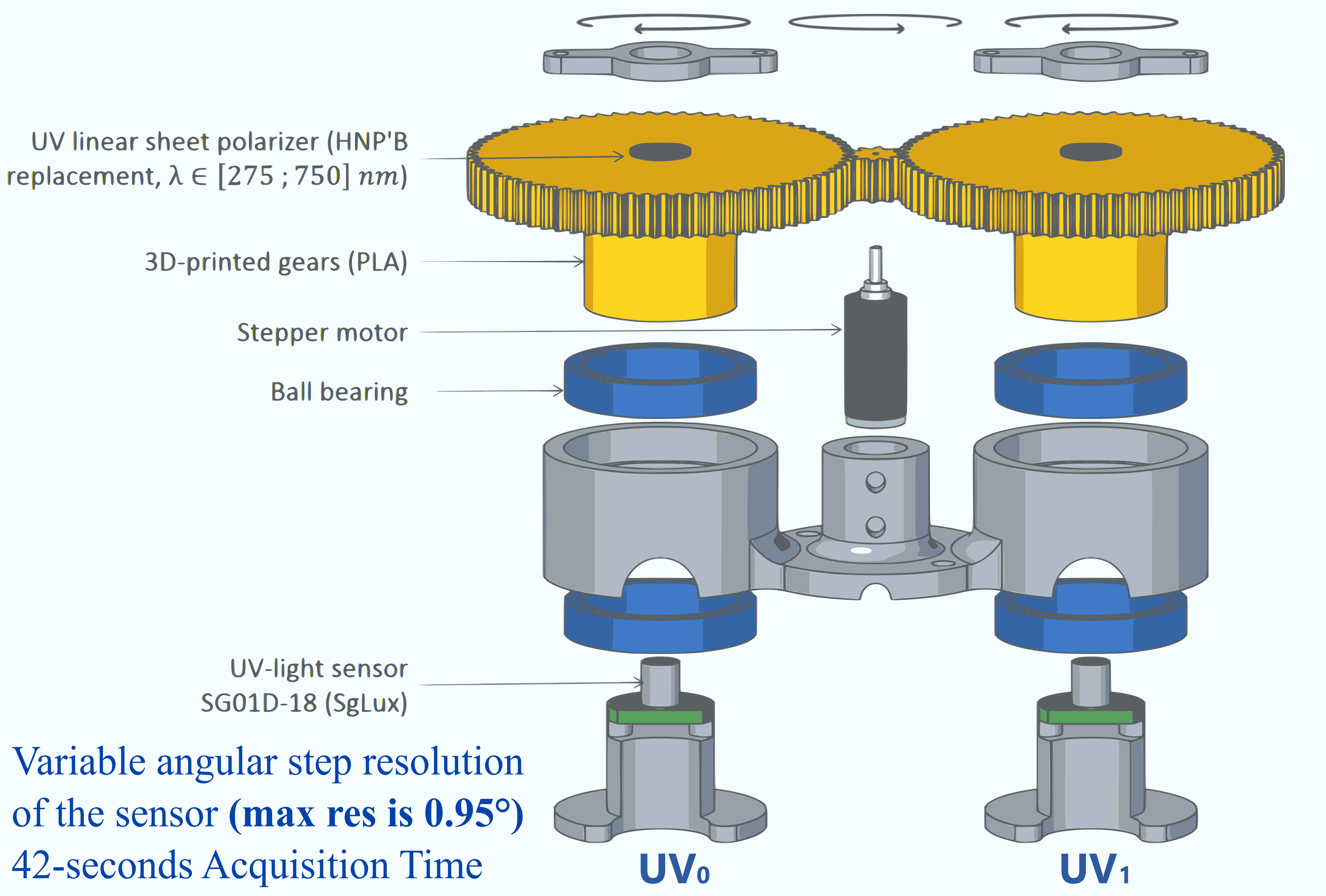
## The polarized light detection in insects




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 $[0, 2\pi]$:

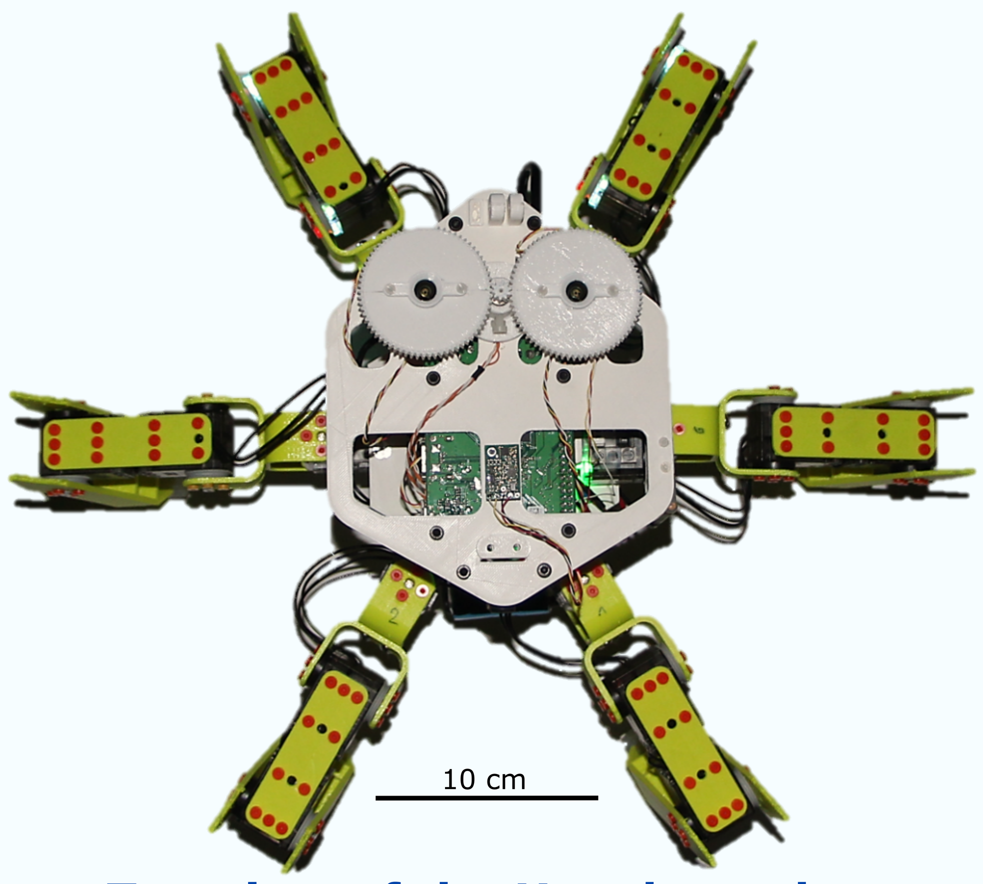
$$\begin{cases} UV_0(x) = A_0 + B_0 \cdot cos(2(x+\psi)) \\ UV_1(x) = A_1 + B_1 \cdot cos(2(x+\psi+\frac{\pi}{2})) \end{cases}$$

where $\psi$ 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:

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

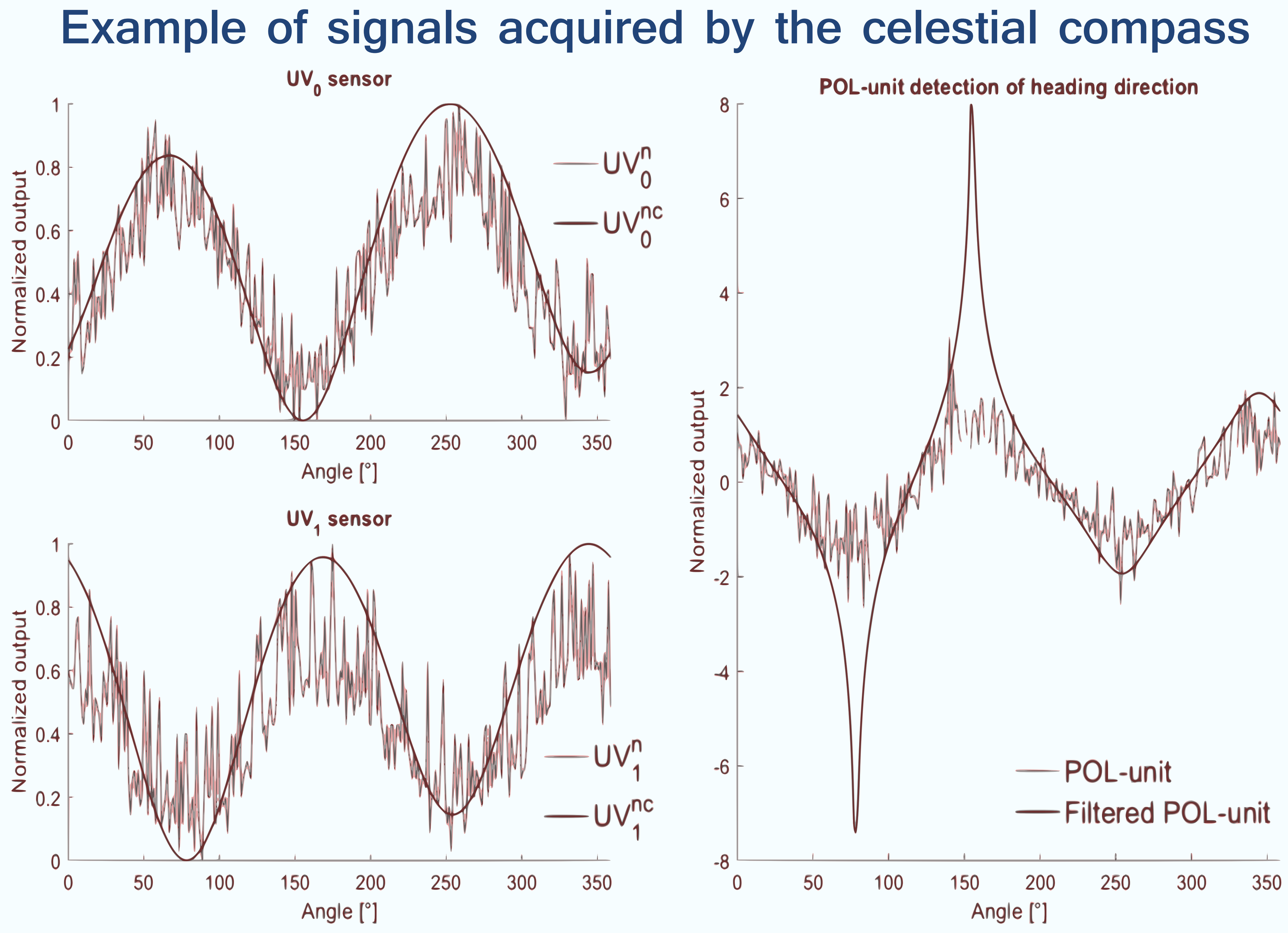
Finally, $\psi$ is computed as follows:

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

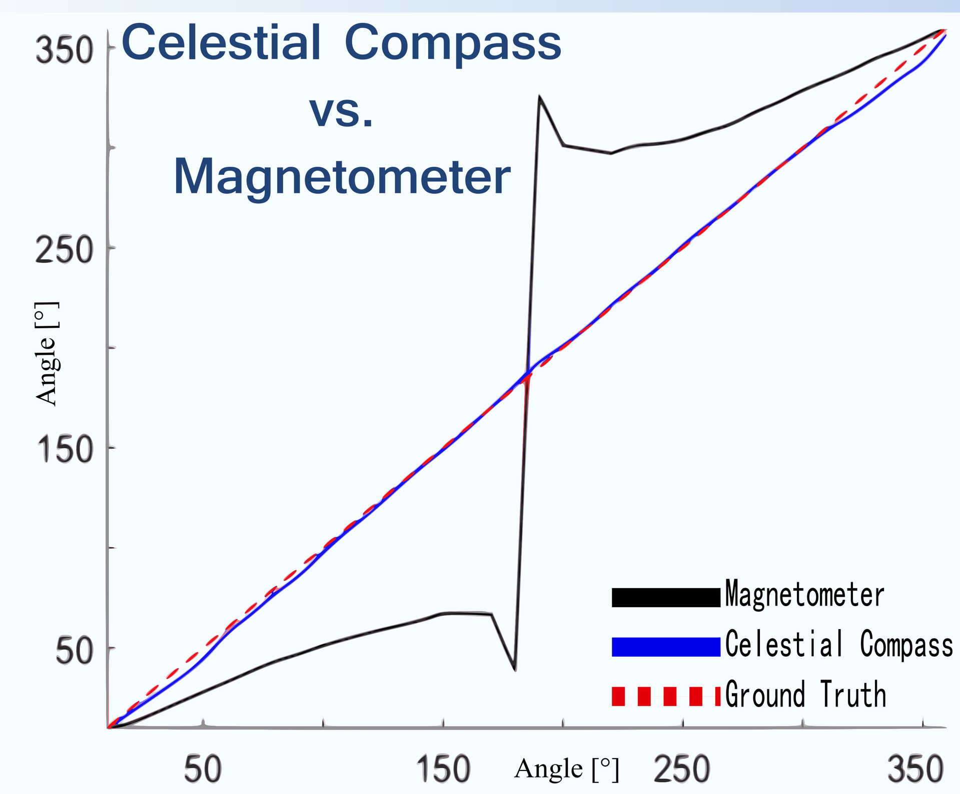



**Top view of the Hexabot robot equipped with the UV-polarized light compass [2].**

Example of signals acquired by the celestial compass



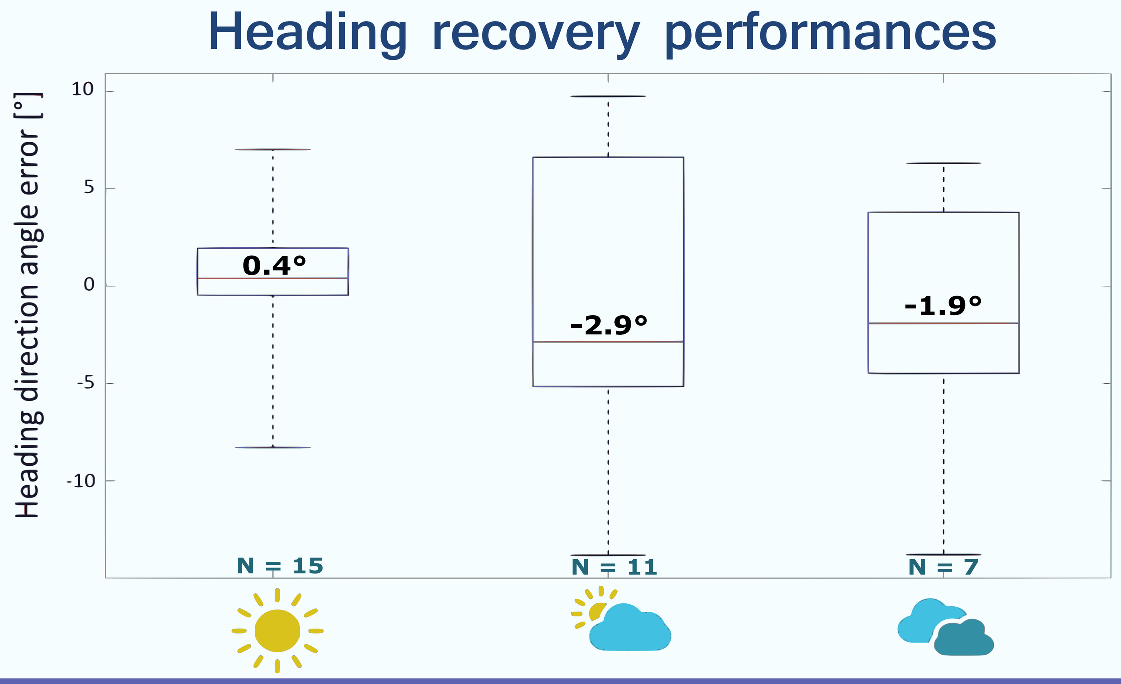

## Results



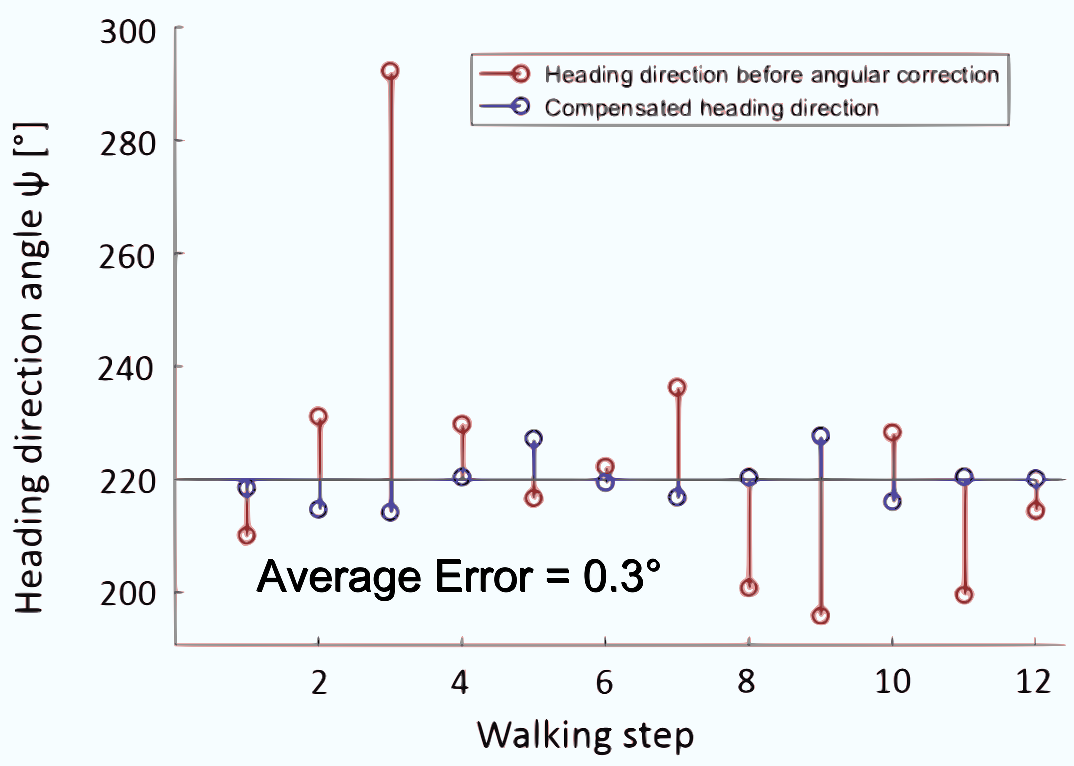

Performances of the celestial compass under various weather conditions [3]

| 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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