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Providing an Autonomous Hexapod Walking Robot with the Ability to Reorientate: Application of a Novel Ant-inspired Celestial Compass

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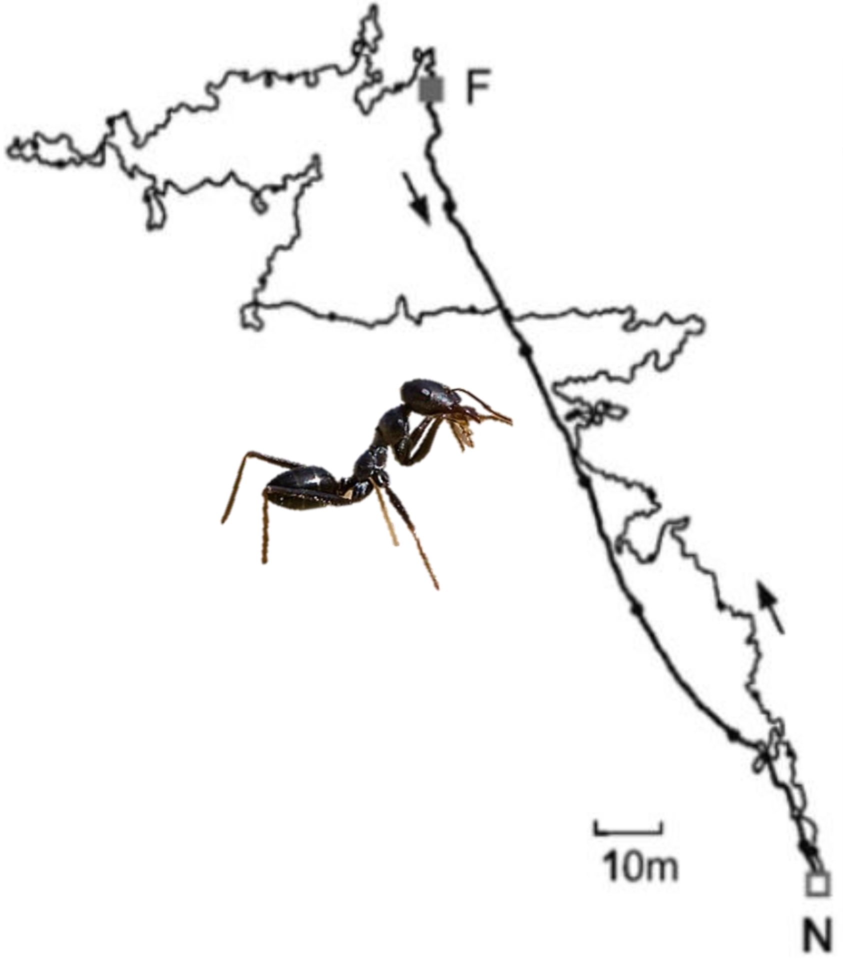
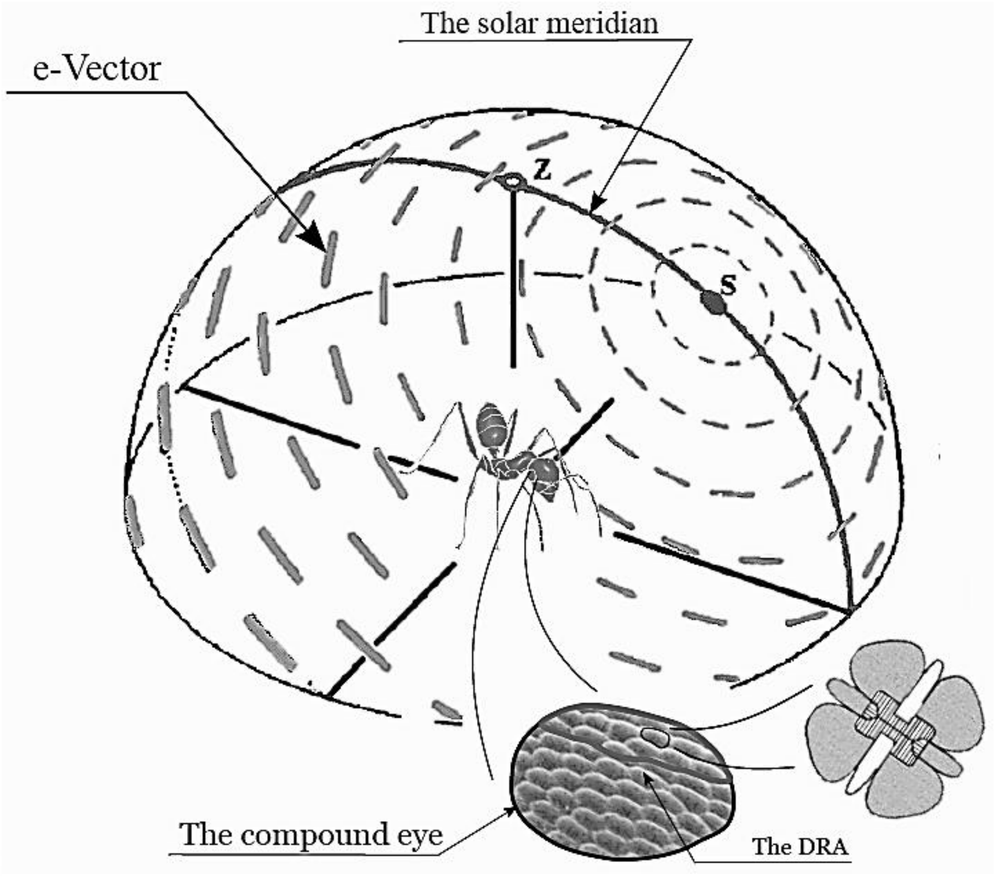
The polarized light detection in insects

Homing behavior in Cataglyphis desert ants



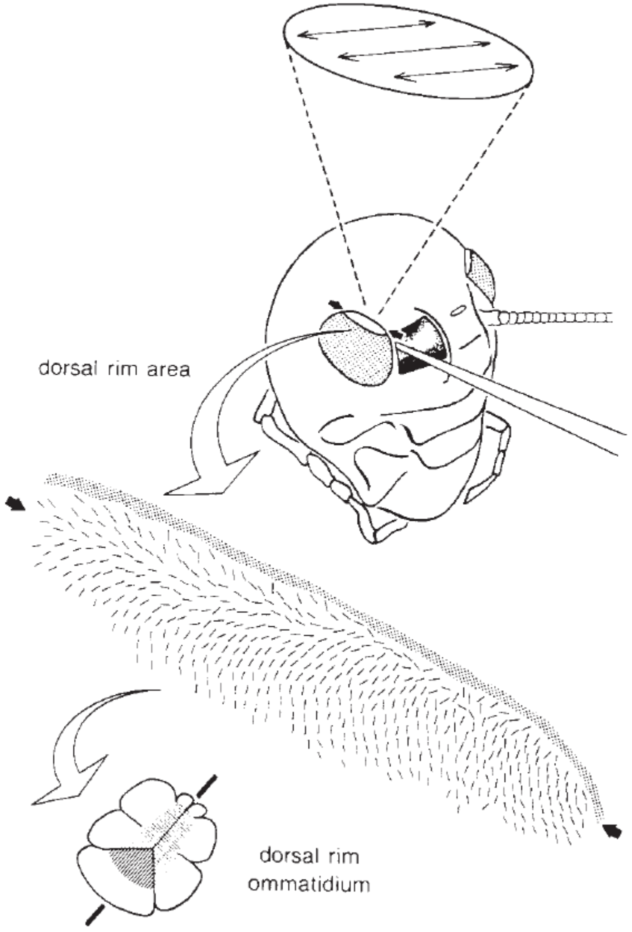
After Wehner, 2009.

The polarized skylight e-Vector pattern



Adapted from Wehner, 1982.

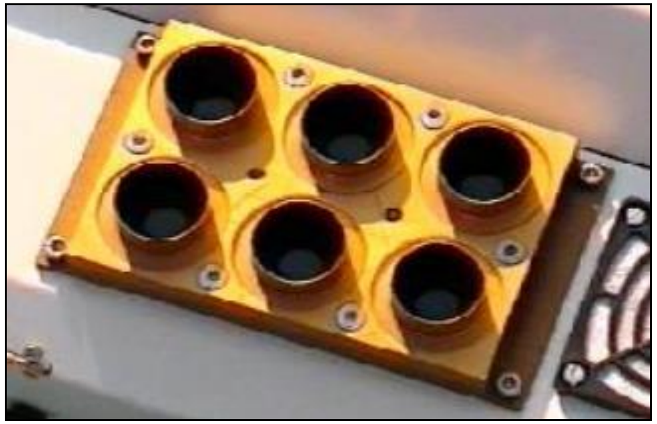
The Dorsal Rim Area (DRA)



After Labhart, 1988.

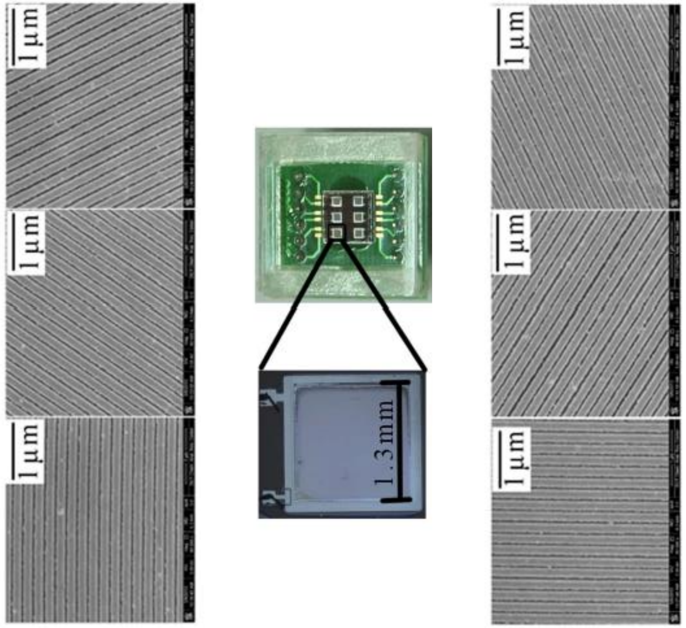
Bio-inspired celestial compass techniques

The Sahabot project, Lambrinos et al., 1997 - 2003



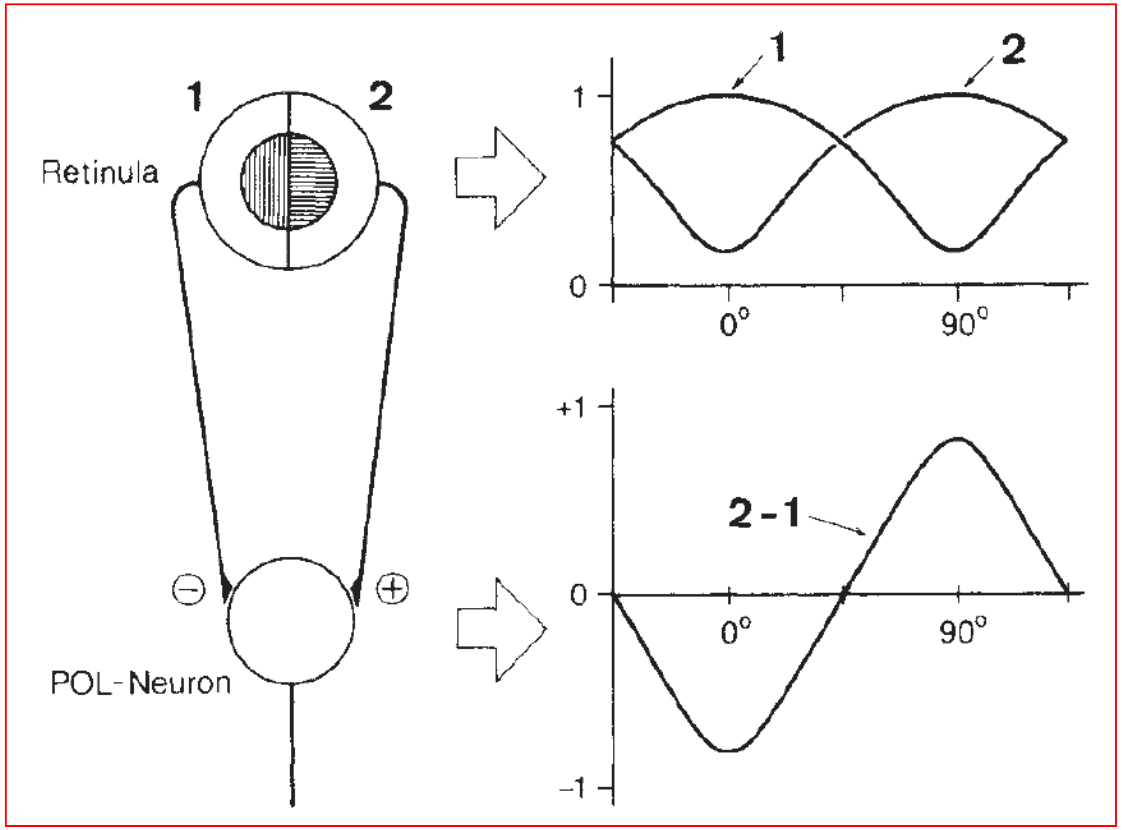
Miniaturizing the Sahabot POL-compass

After Chu et al., 2014.



The bio-inspired model

After Labhart, 1988.

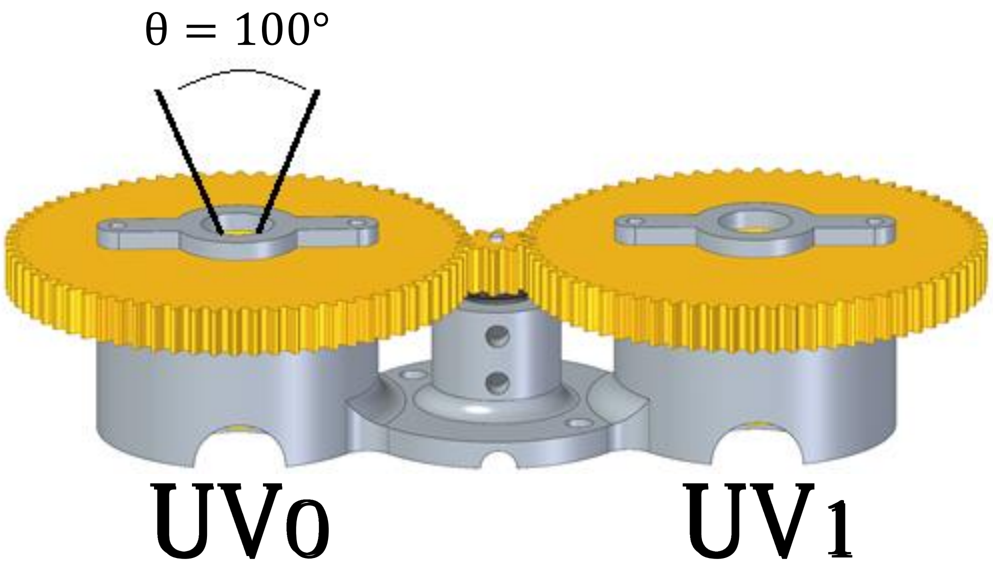


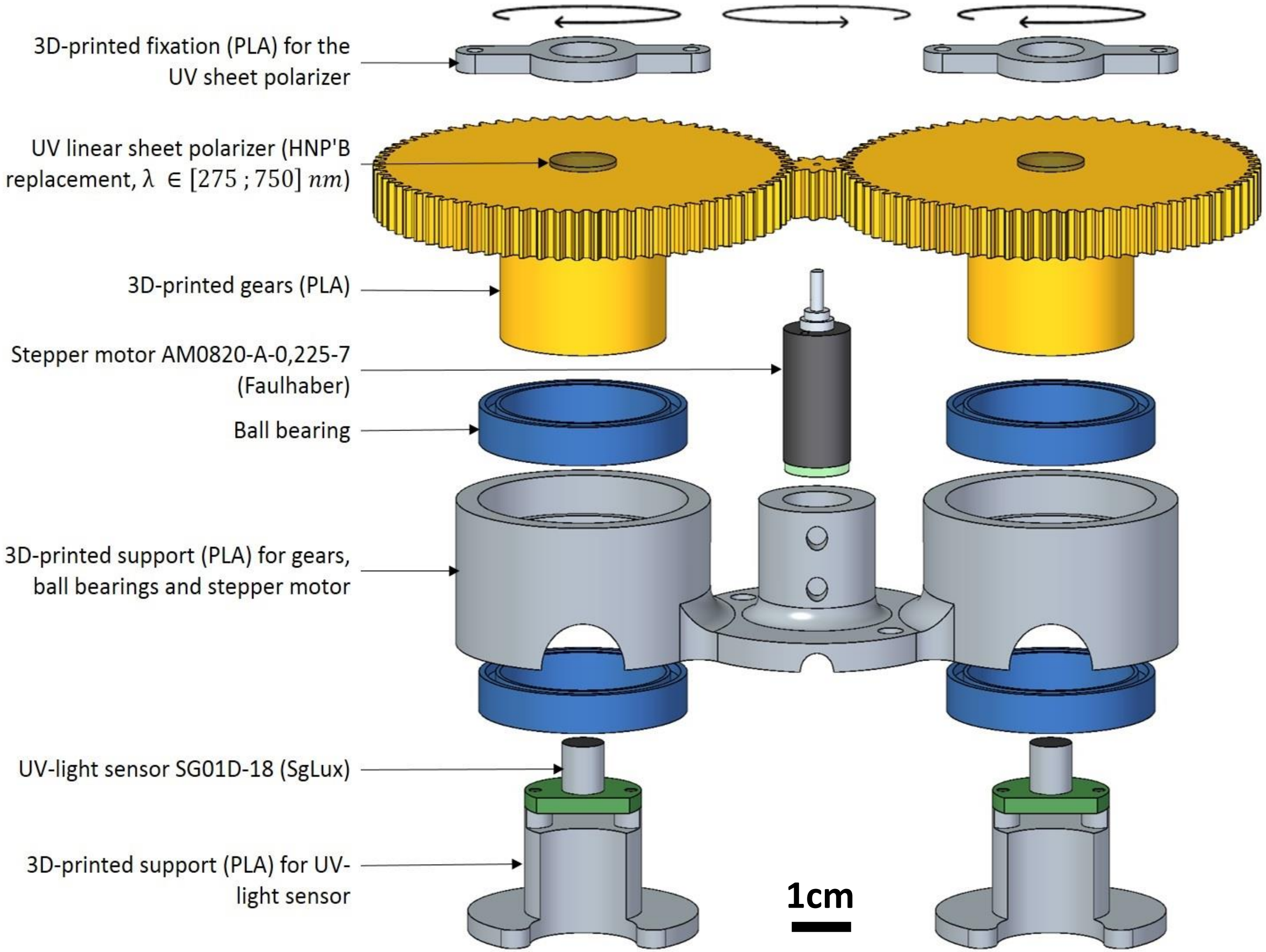
Our UV-polarized light celestial compass

Angular resolution arbitrarily set to 1.29°

for an acquisition time of 42s

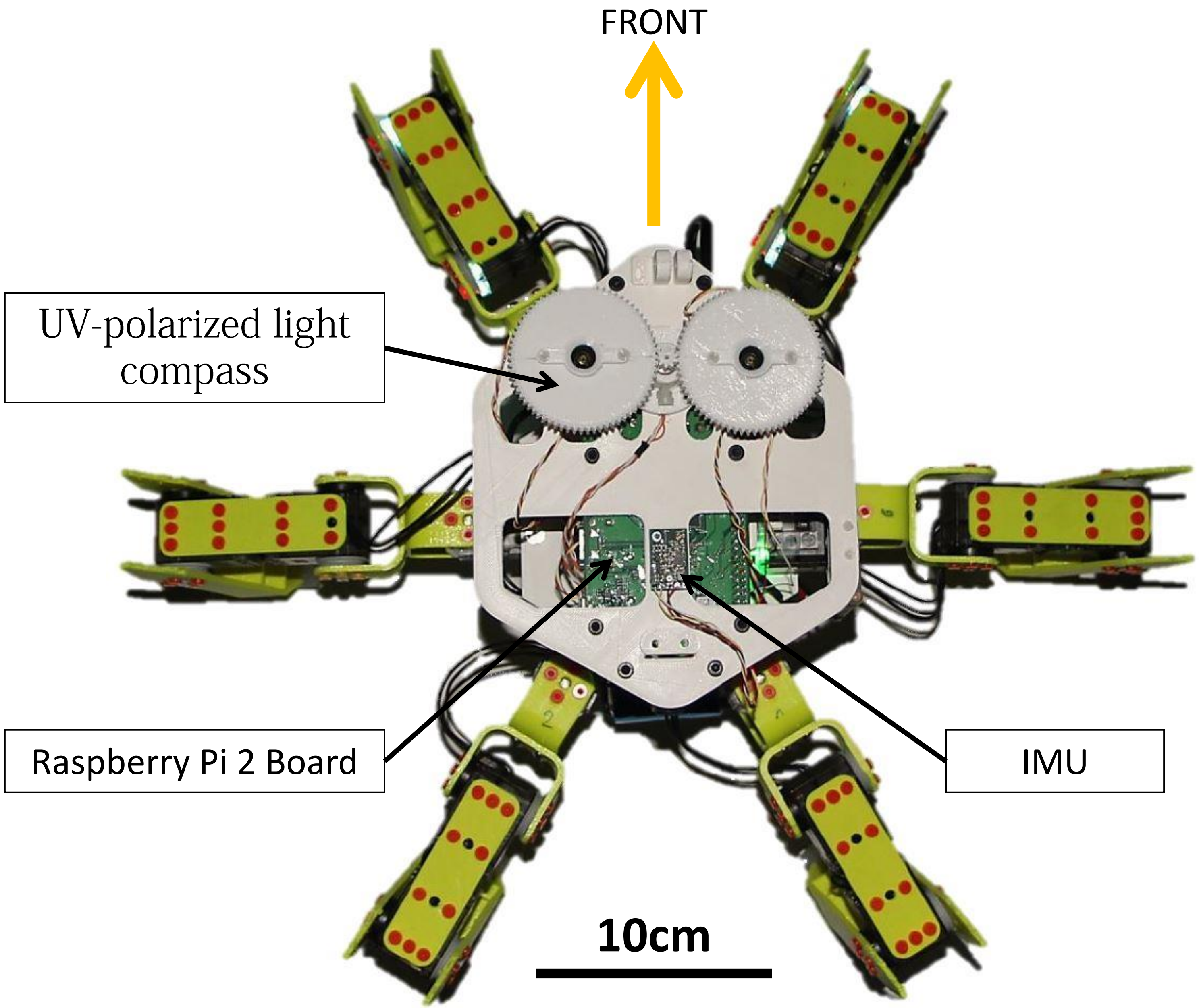
Spectral sensitivity: 275 – 375 nm

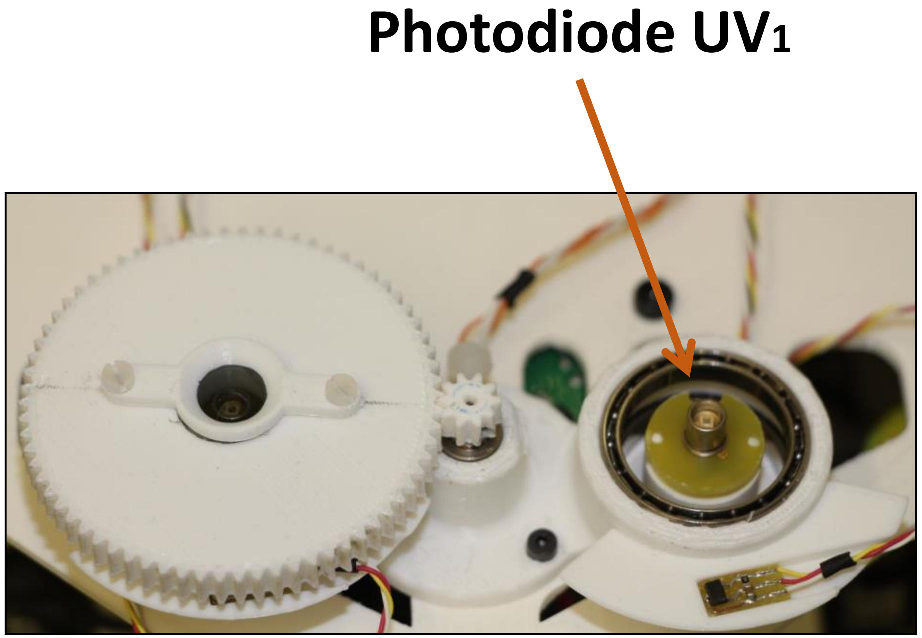


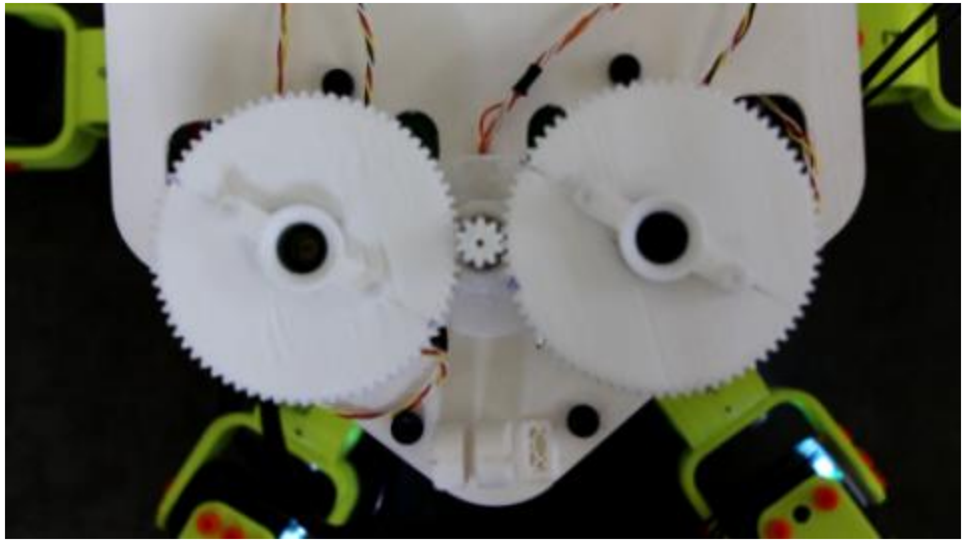


Dupeyroux et al., 2017

The robotic implementation







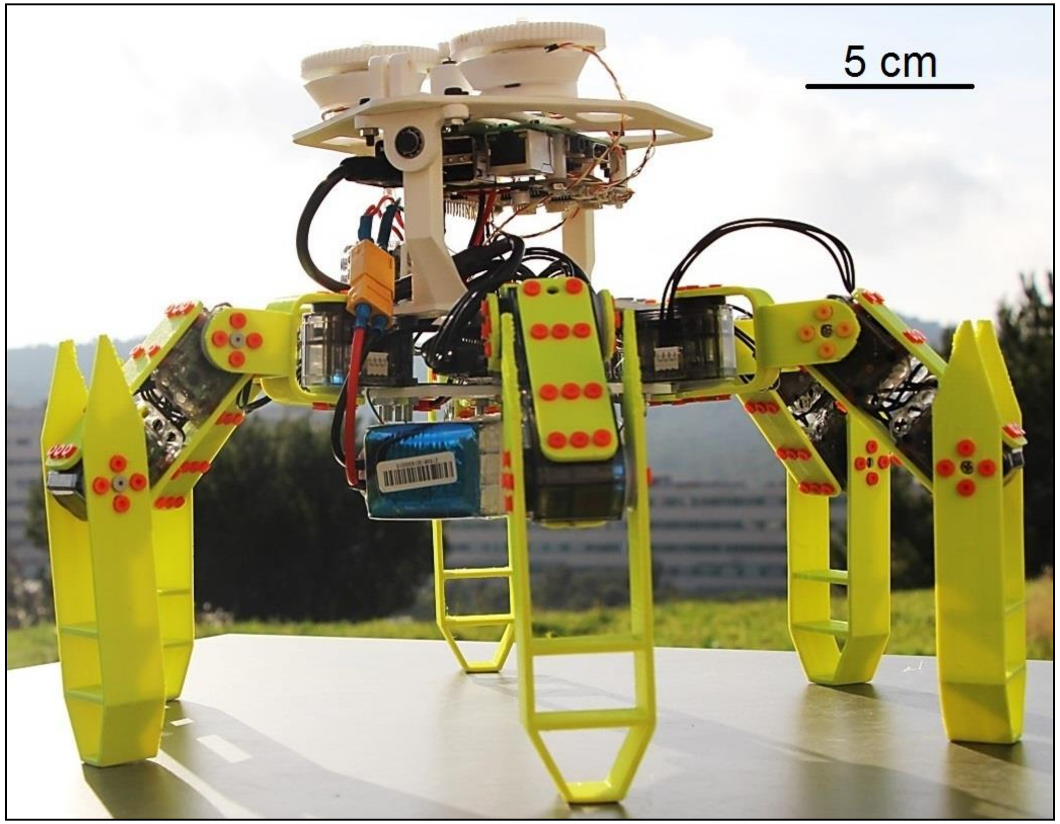
The hexapod walking robotic platform: HEXABOT

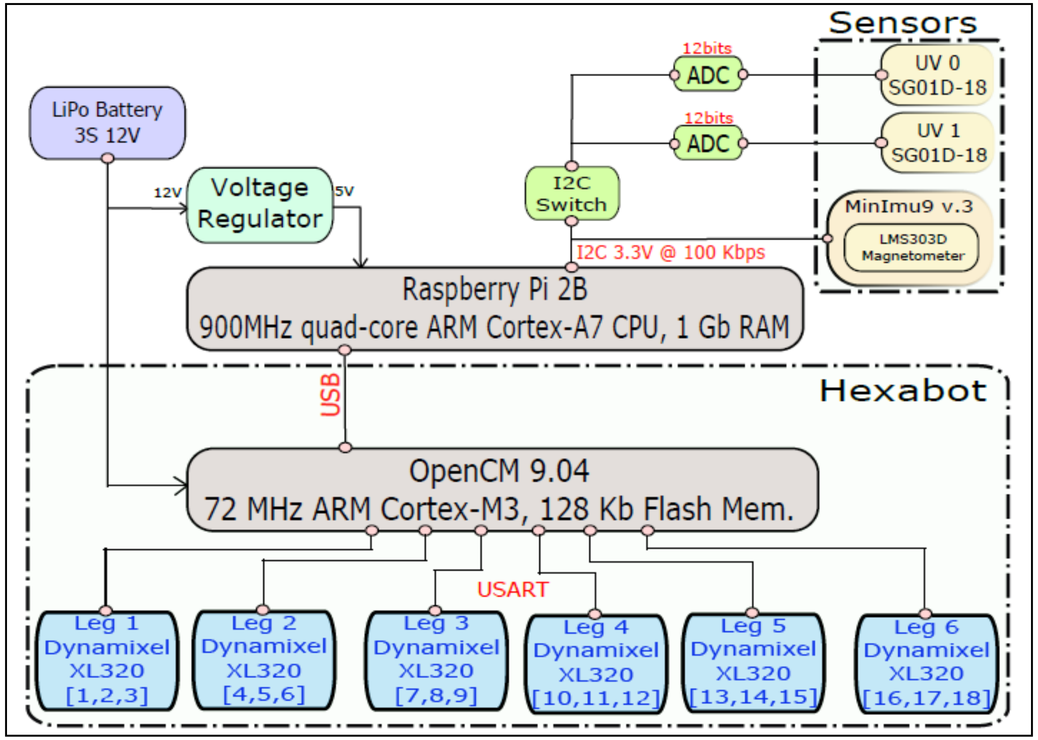
3 Dynamixel XL-320 servos per leg

Overall weight with batteries: 925g

Maximum walking speed ~ 35 cm/s

Tripod gait locomotion pattern

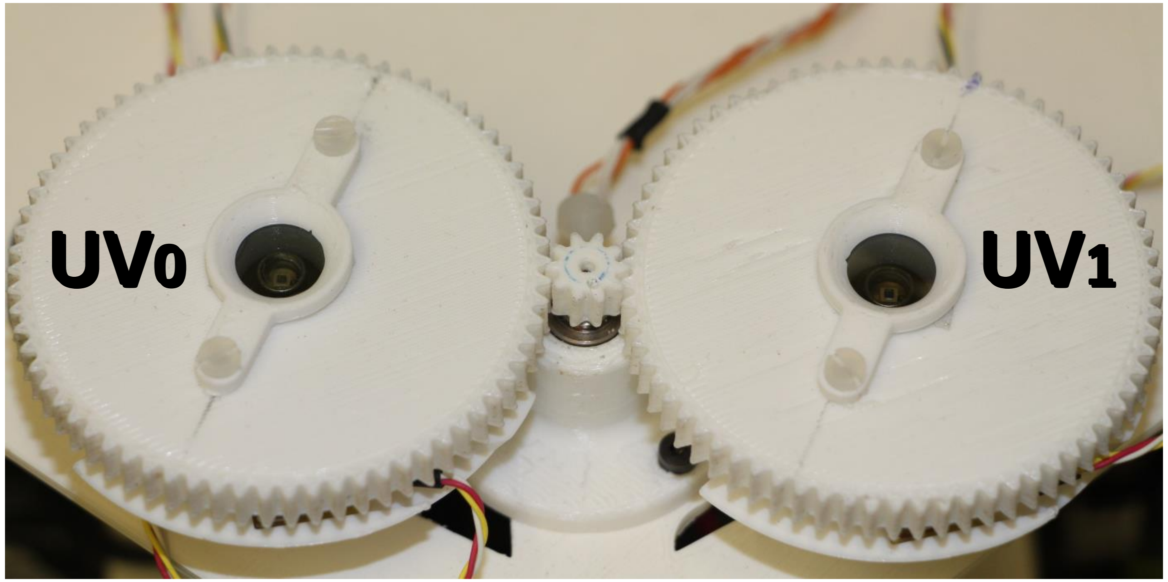




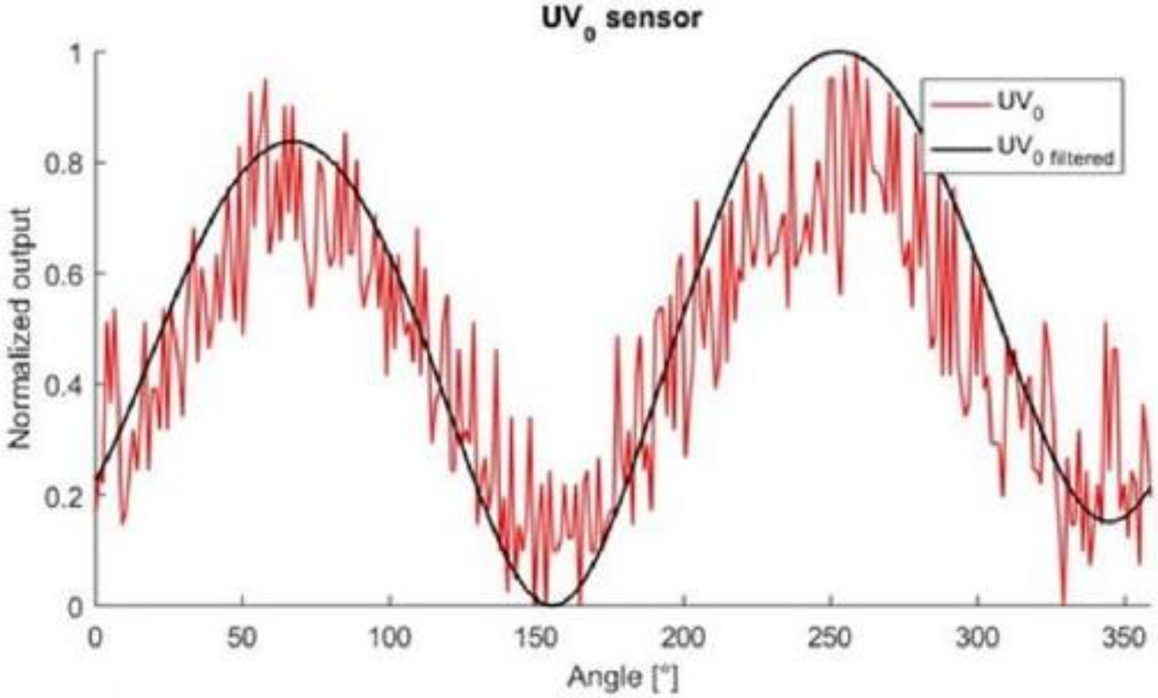
	Speed	Hexabot	Ants
Roll	50%	4.5°	10°
	75%	6.7°	
	100%	9.0°	
Pitch	50%	4.4°	60°
	75%	5.4°	
	100%	9.9°	
Yaw	50%	19.8°	
	75%	19.8°	
	100%	19.8°	

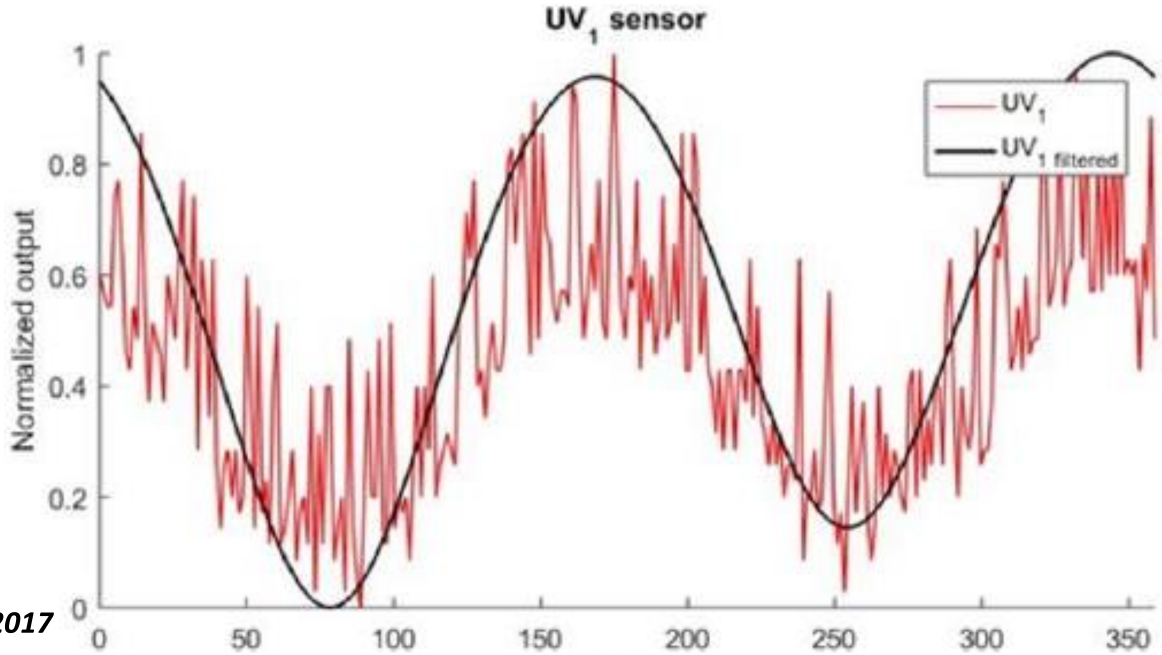
Dupeyroux et al., 2017

How does it work ? (1)



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



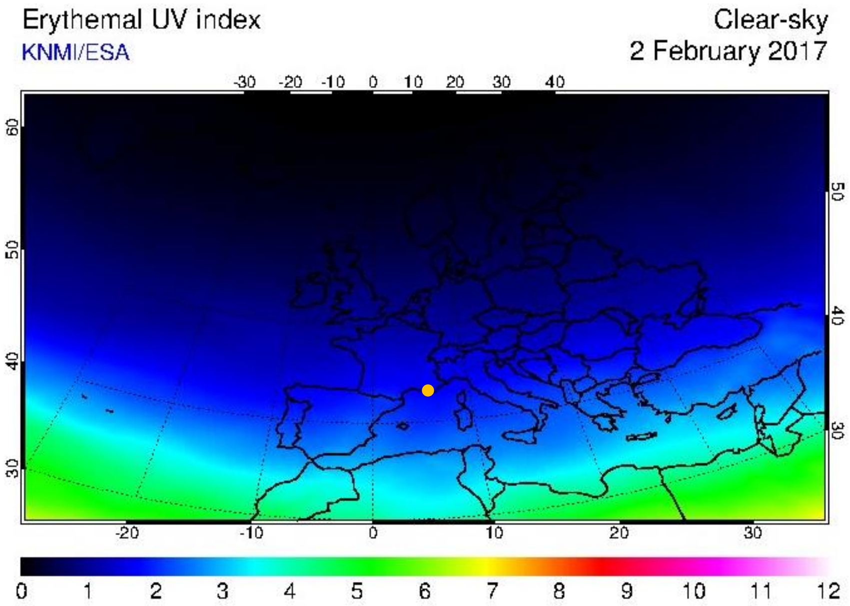


Dupeyroux et al., 2017

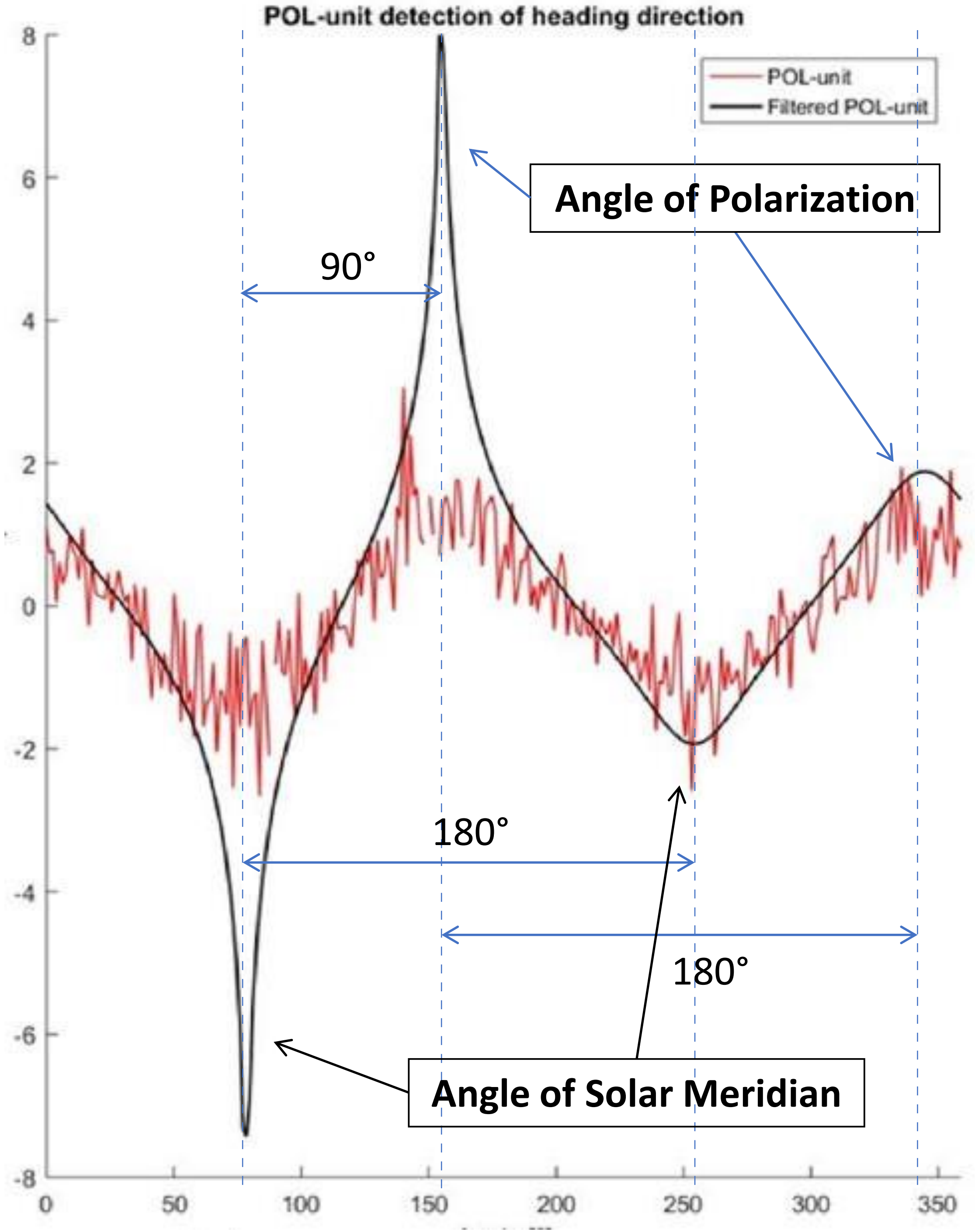
How does it work ? (2)

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

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

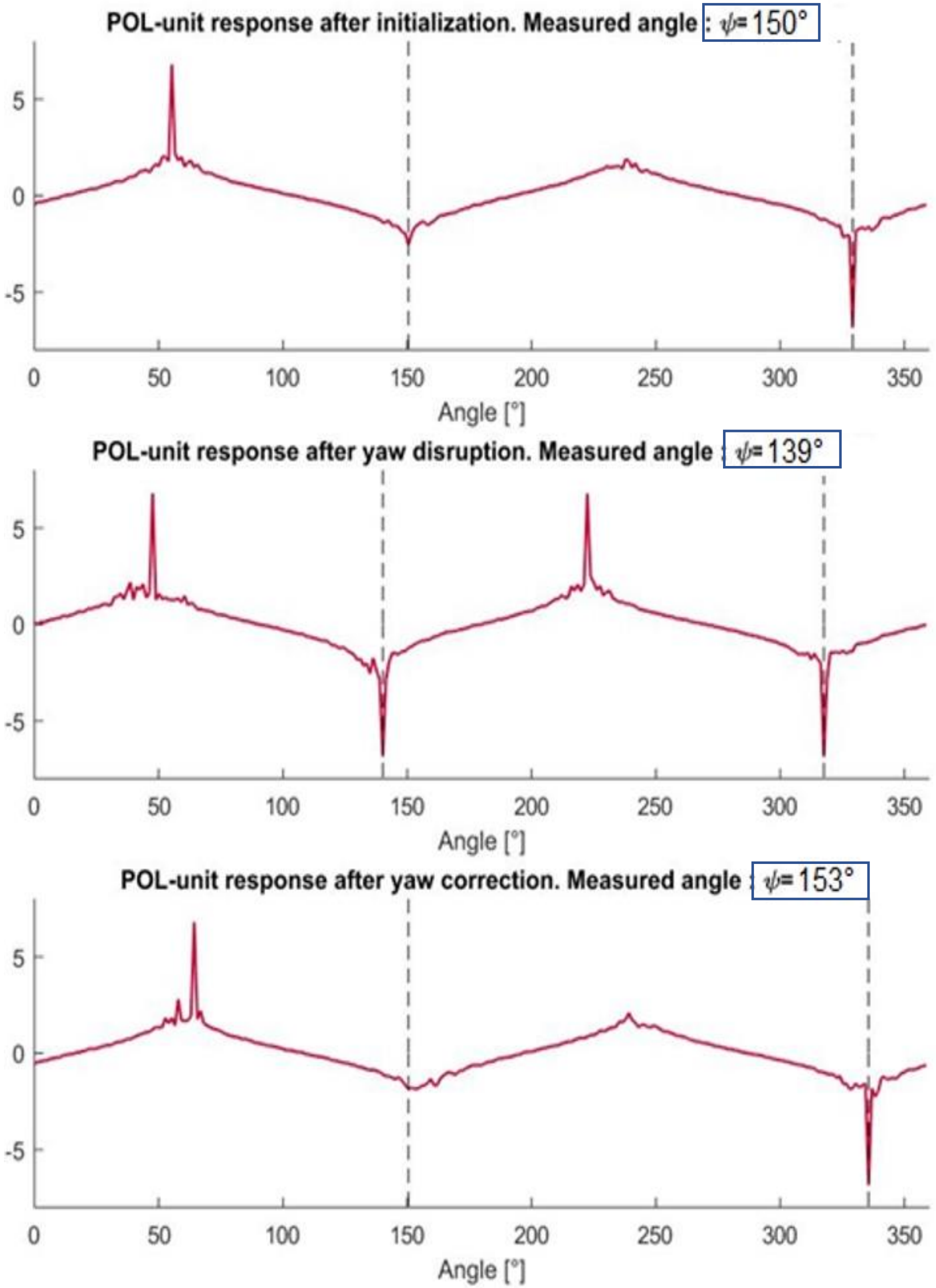


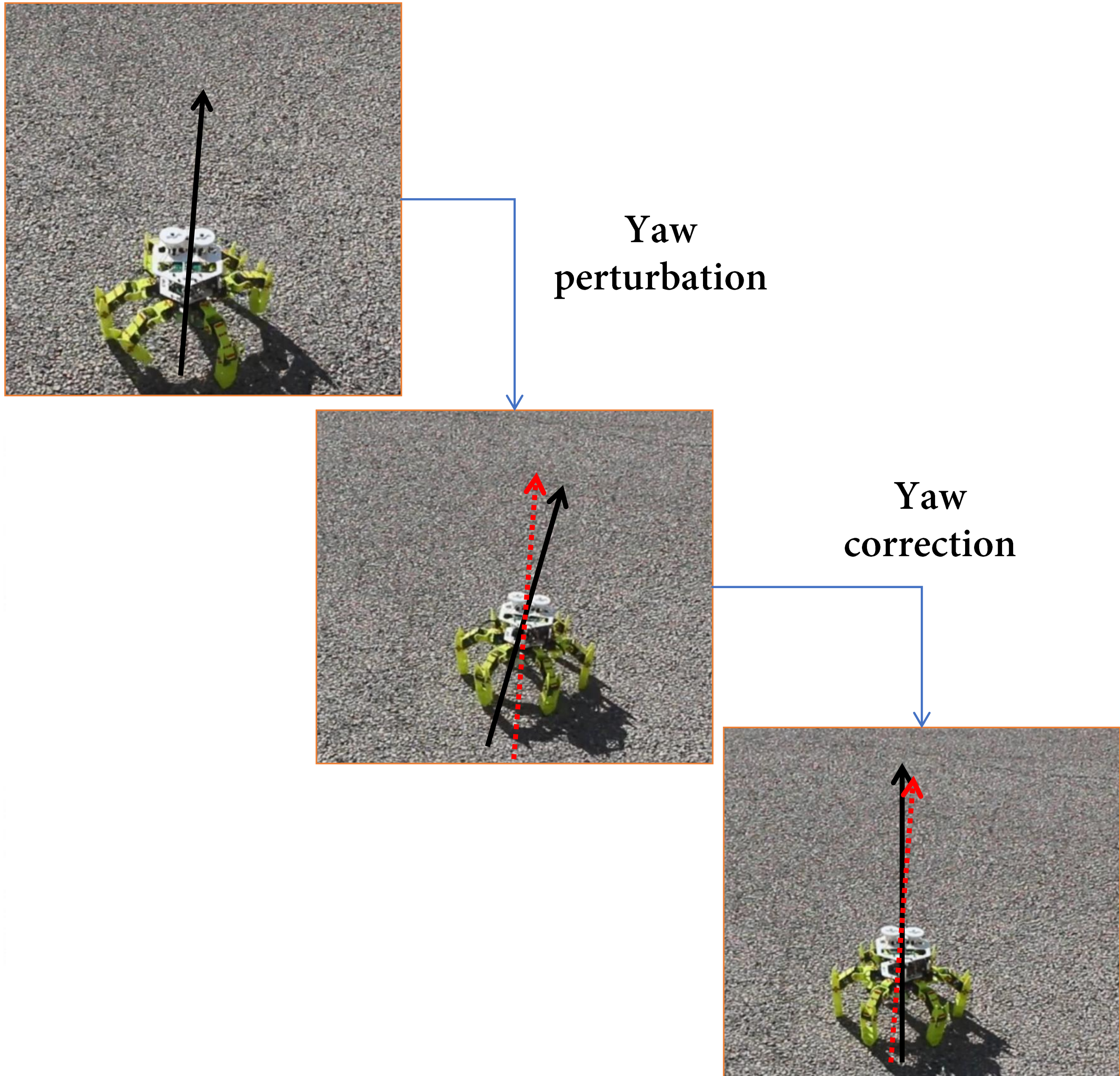
Variable Sky
UV-index = 1



 Dupeyroux et al., 2017

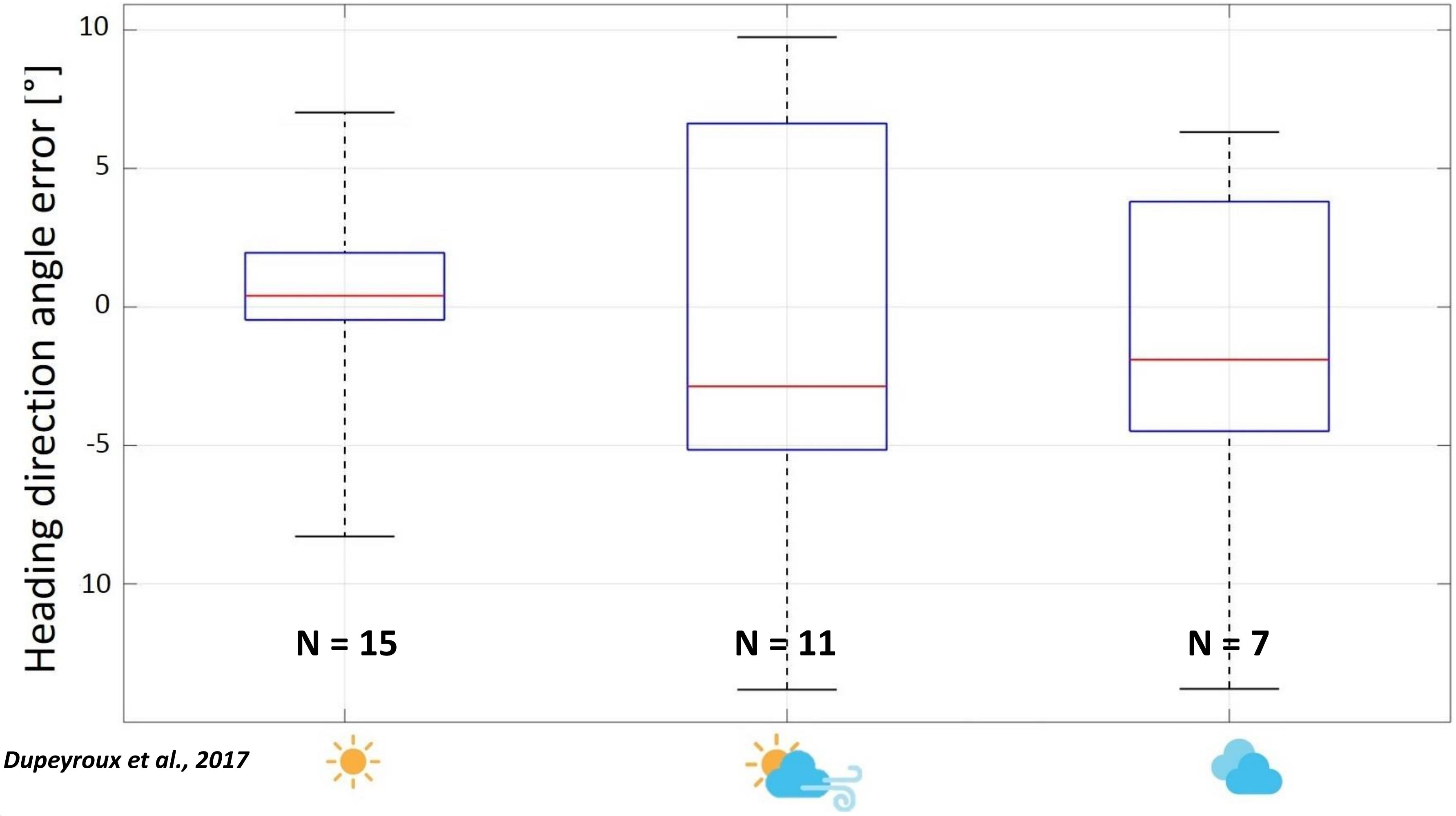
Heading direction recovery (1)





Heading direction recovery (2)

Performances of open-loop reorientation using the POL-compass after yaw displacements under various weather conditions. UV-index from 1 to 2.



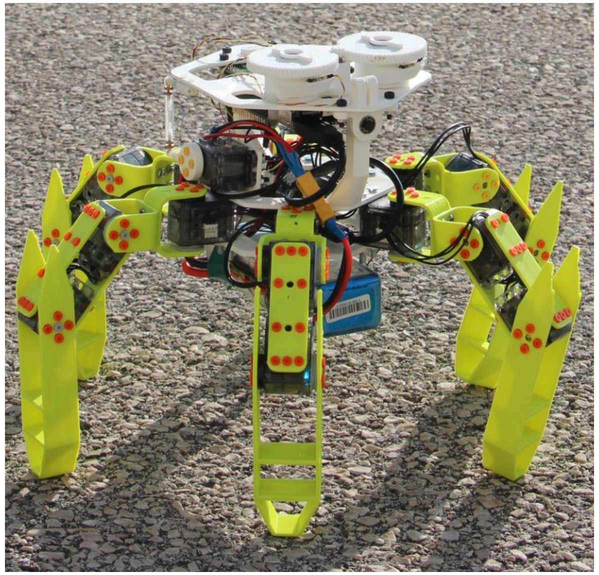
Dupeyroux et al., 2017

$\overline{Err}_{ClearSky} = 0.4°$

$\overline{Err}_{OvercastSky} = -1.9°$

$\overline{Err}_{VariableSky} = -2.9°$

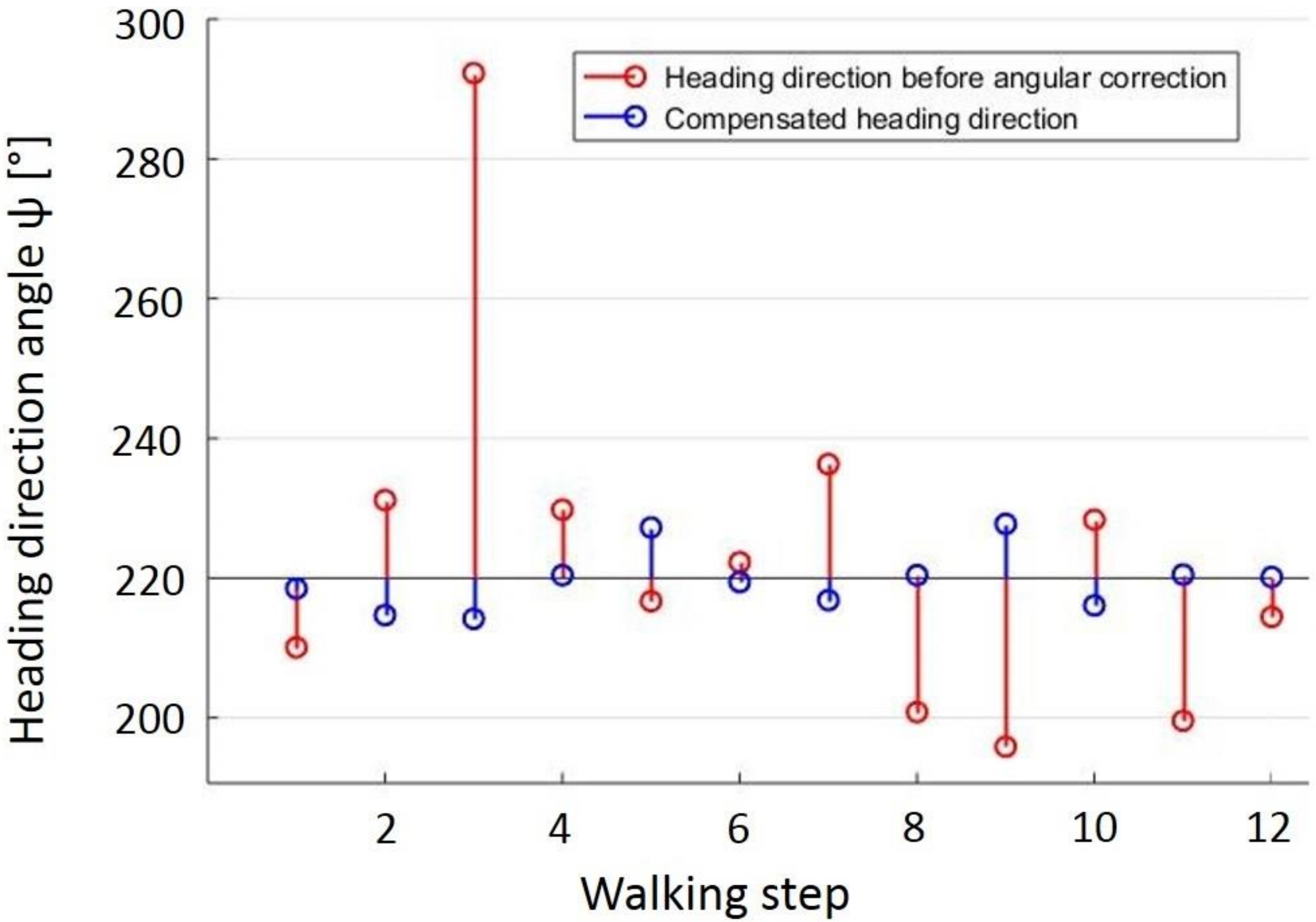
42-second acquisition time per POL-measurement



Heading-lock over a straight-forward walking task

Heading-lock over a straight-forward walking task.
Clear sky conditions, UV-index = 2.

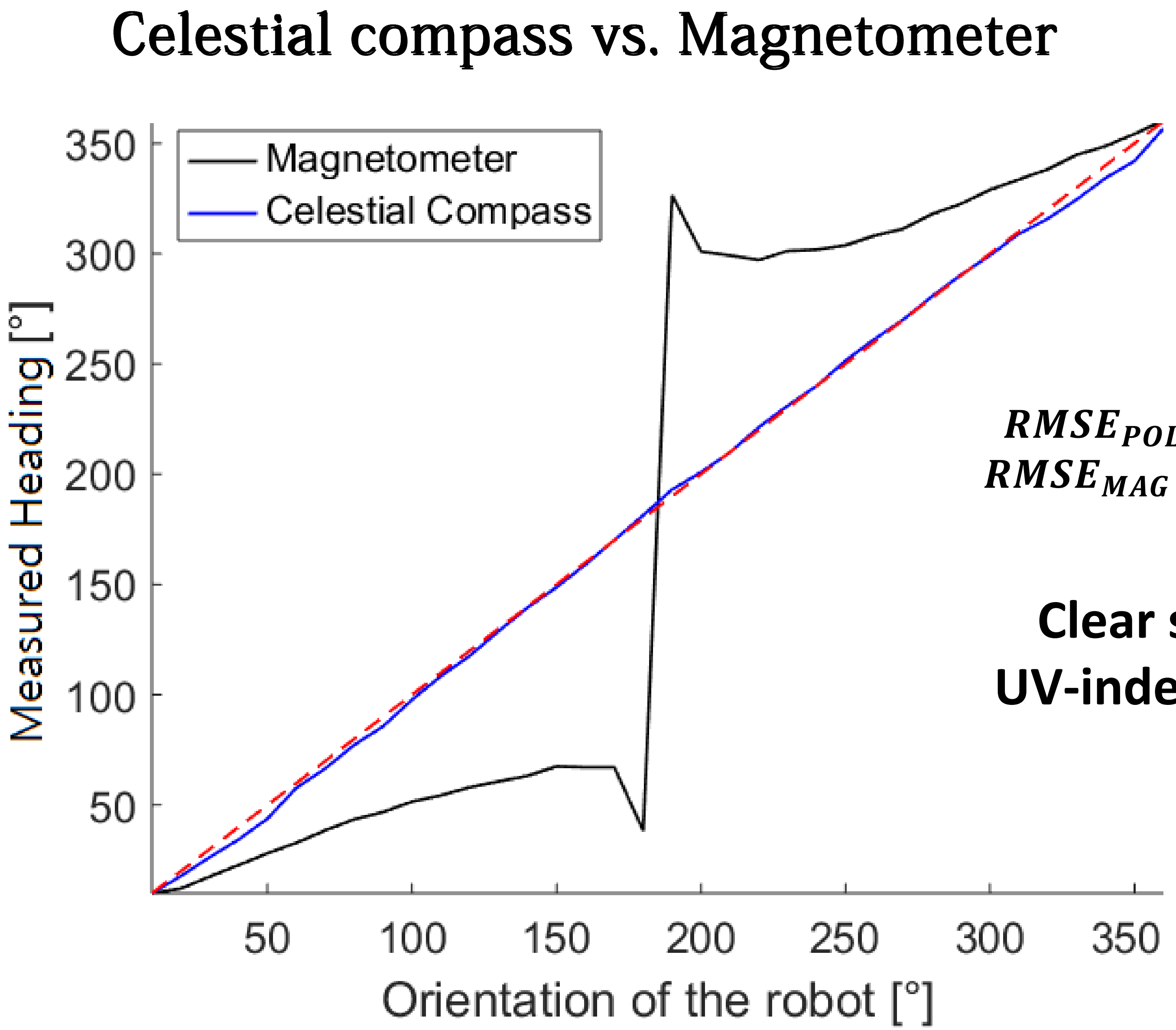
Dupeyroux et al., 2017



$\overline{Err} = \; \mathbf{0.3°}$

The celestial compass as a spare to traditional methods

Dupeyroux et al., 2017



$RMSE_{POL} = 3°$

$RMSE_{MAG} = 61°$

Clear sky

UV-index = 6

Conclusion and perspectives

- UV-index between 1 and 2; 42-second acquisition time, to be reduced at 20s.
- Heading direction error from **0.3° under clear sky** to 2.9° under worse weather conditions, both with very low UV index. Highly **reliable** celestial compass.
- Sensory modalities very similar to those of insects: **robotic insect embodiment.**
- Even under poor weather conditions, these results suggest **interesting precision** to make the optical compass **suitable for field robotics** as a spare sensor as it is unsensitive to magnetic interferences.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