

Colloque PEPS « Ingénierie Inspirée par la Nature »

MiMiC-ANT project

Study of locomotion during load transport in ants:  
application to hexapod robotics

Presented on June 21, 2021, by

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Pierre Moretto<sup>2</sup>, and Stéphane Viollet<sup>1</sup>**

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# Contents and research question



*Cataglyphis nodus*

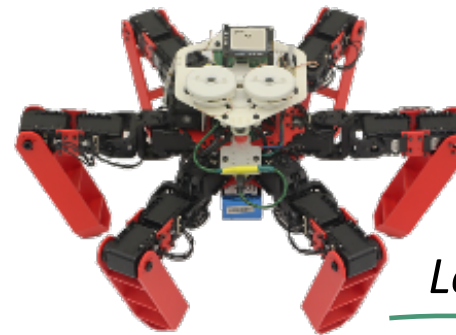
10~20 mg

Range 150 m

Load 10~15 times its weight



Rebuilding



*AntBot*

2.3 kg

Range 15 m

Load 0.3 times its weight



Understanding the gap

Knowledge & modelling in ants



UNIVERSITÉ  
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Robotic innovation

INSTITUT  
DES SCIENCES  
DU MOUVEMENT  
JULES  
MAREY

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université  
Socialement engagée

How can we take inspiration from ants  
to improve the load transport in hexapod robotics?

# Why studying locomotion in ants?



© E. Economo

**High biological diversity  $\approx$   
13,000 species**



*Arboreal ants*

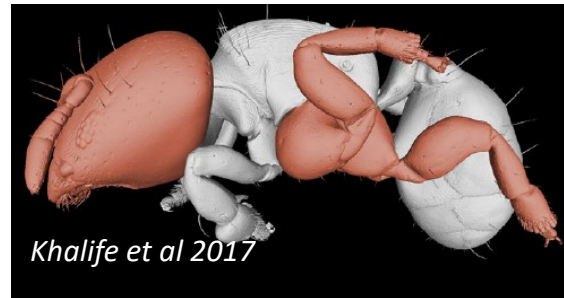


*Ground dwelling ants*

**High diversity of  
walking support**



*Cephalotes*



*Khalife et al 2017*

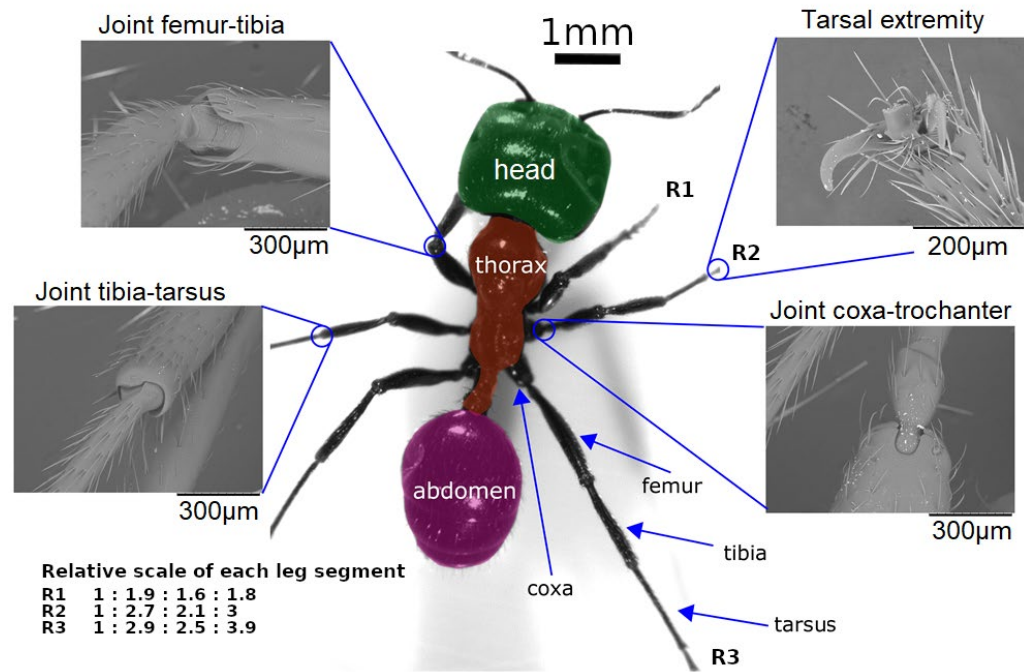
*Melissotarsus*

**High morphological  
diversity**



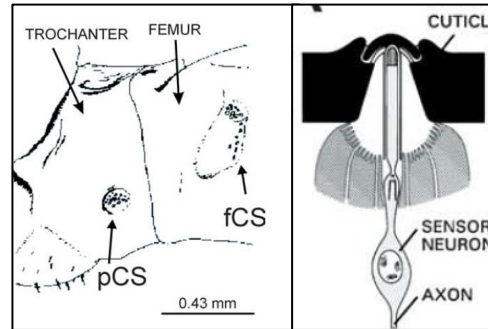
**Individual and collective transport**

# Ant morphology and anatomy

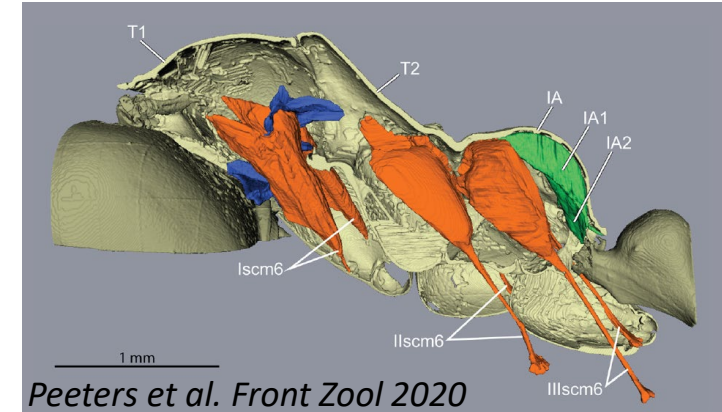


**External anatomy**

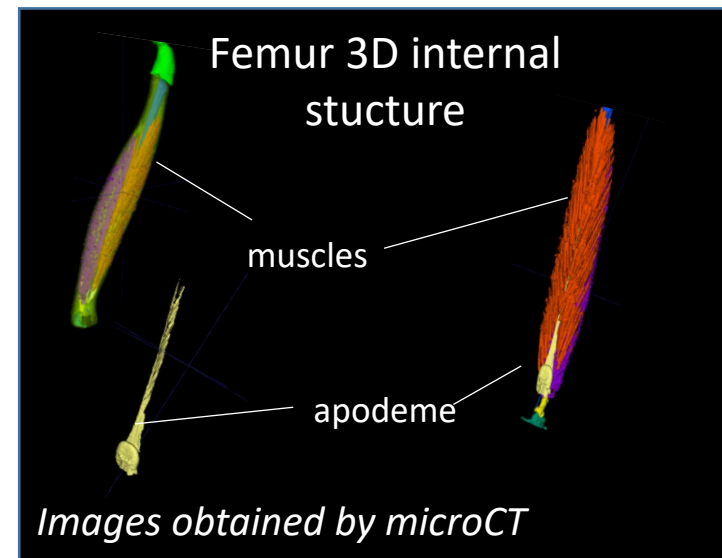
## Campaniform sensillum



*Zill et al. Athr Struct Dev 2004*

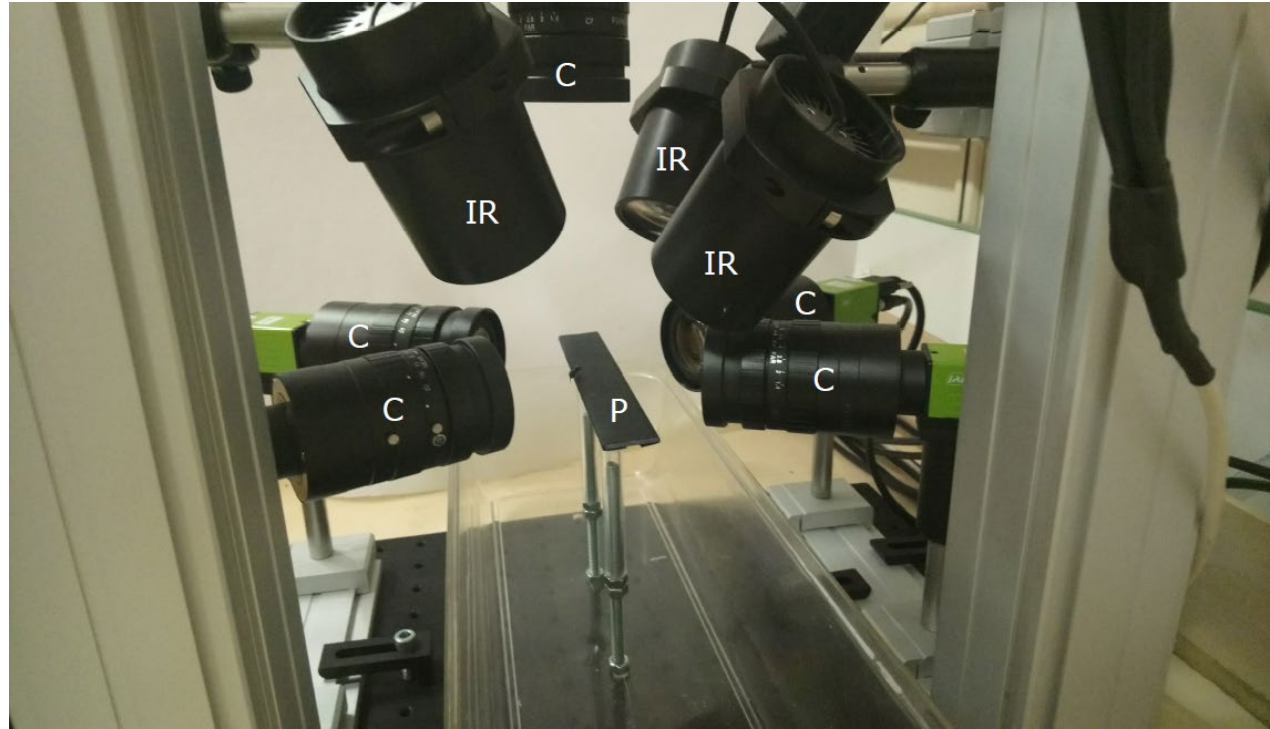


*Peeters et al. Front Zool 2020*



**Internal anatomy**

# Experimental setup



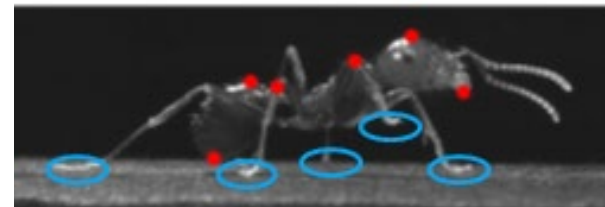
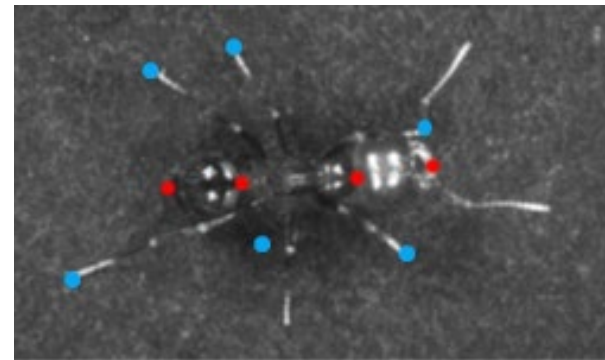
**C:** 5 synchronized cameras filming at 250Hz and 30  $\mu\text{m}/\text{pixels}$

**IR:** 4 infrared strobe spots synchronized with the cameras

**P:** walking platform for the ants

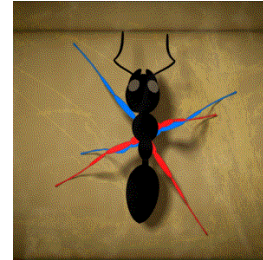
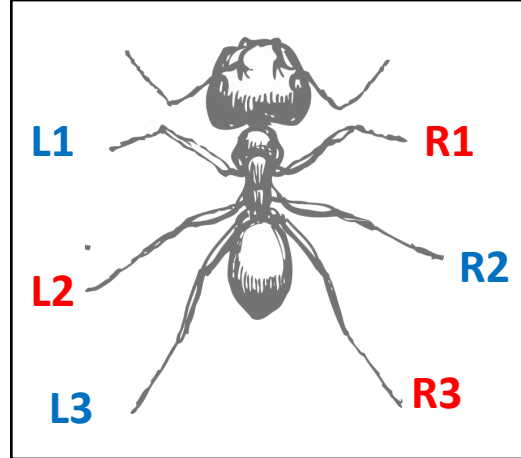


*Locomotion of a loaded ant*

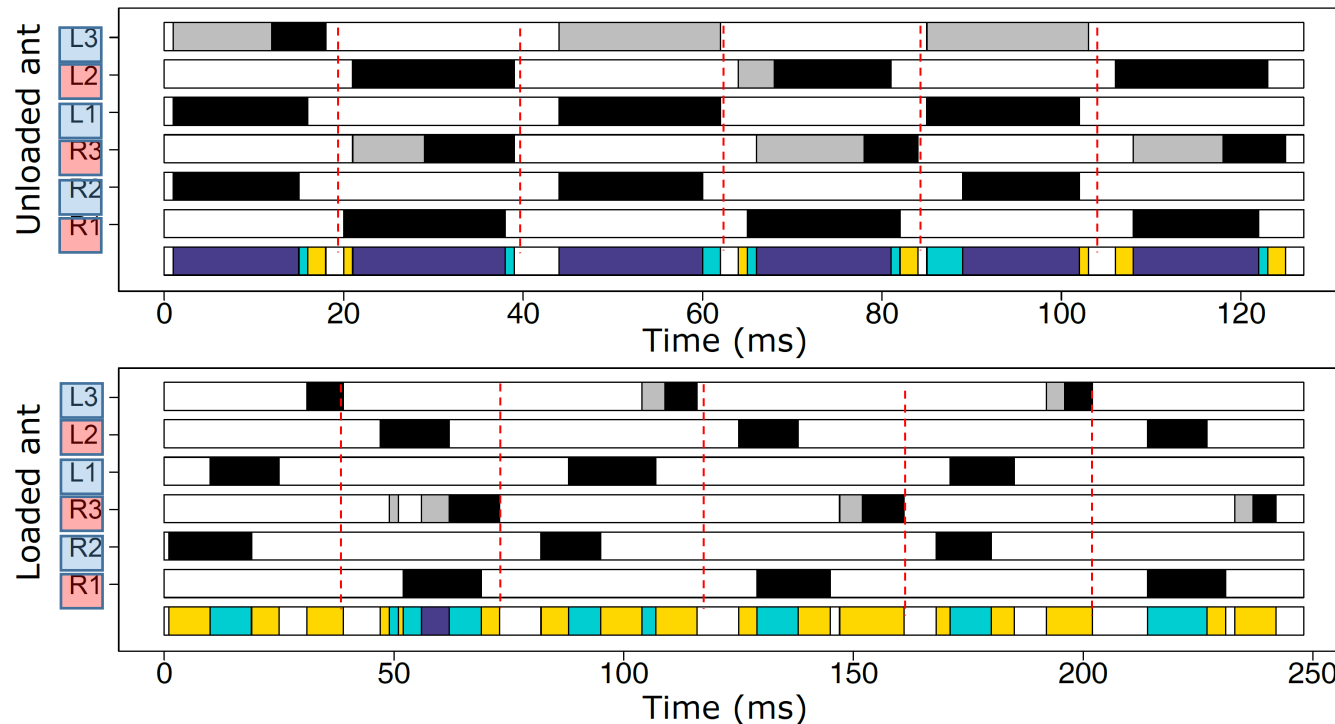


*Tracked points*

# Biological results



State of the leg :  Clung ;  Swung ;  Dragged  
 Legs in contact with the ground :  6 ;  5 ;  4 ;  3



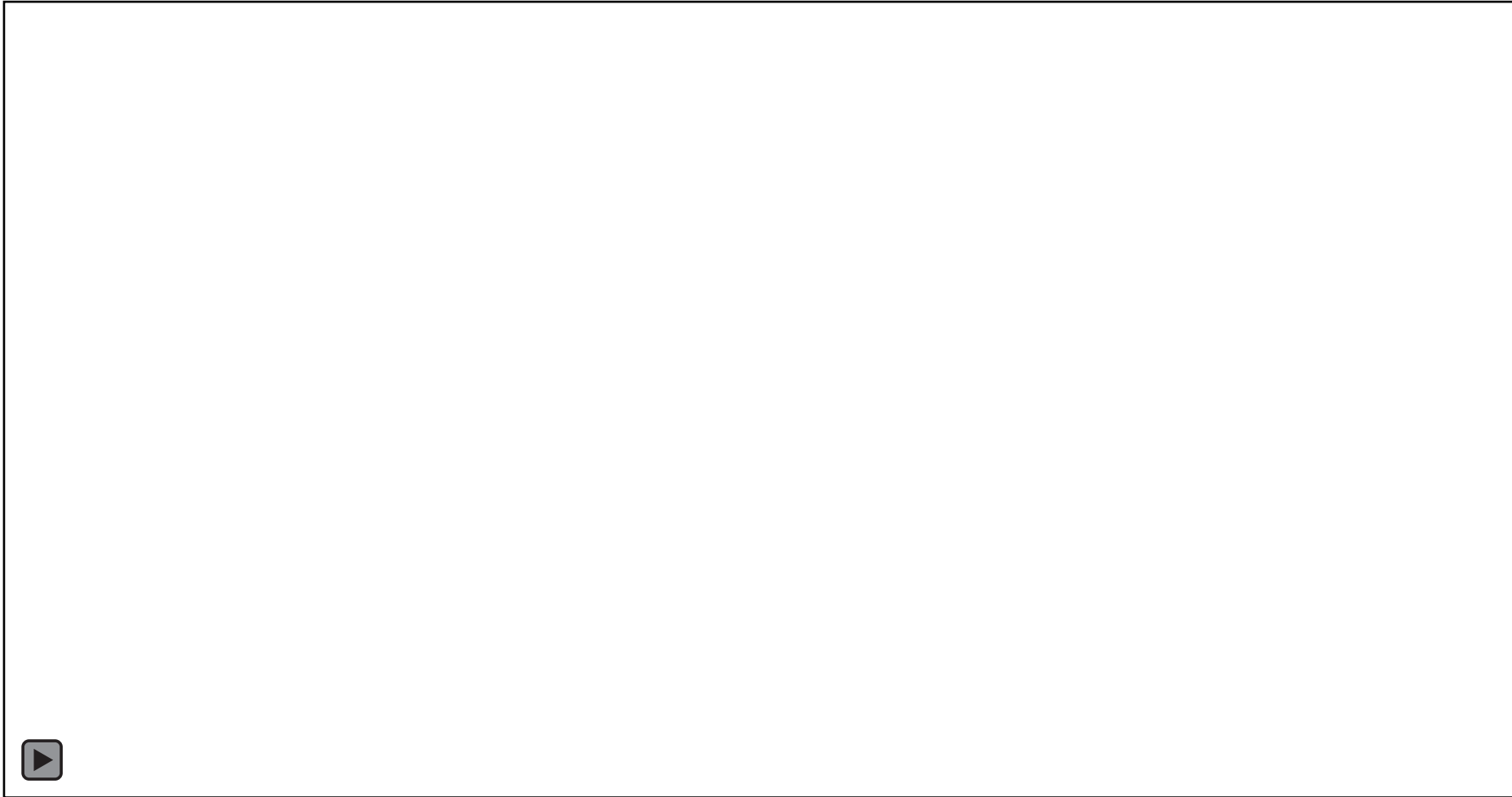
**Example of a podogram of an unloaded (top) and loaded ant (bottom – load ratio ≈ 5)**

## Gait alteration in loaded ants compared to unloaded ants

- more legs are in contact with the ground at any moment and midlegs are more distant from the sagittal body axis
  - **Increase** the size of the polygon of support and hence the **stability**
- Stride length remains the same but stride frequency decreases
  - **Decrease** of walking **speed**
- Hind legs are less dragged
  - ants **cling to the substrate with the claws** of their hind legs to avoid falling over

Merienne, H., Latil, G., Moretto, P., & Fourcassié, V. (2020). Walking kinematics in the polymorphic seed harvester ant *Messor barbarus*: influence of body size and load carriage. *Journal of Experimental Biology*, 223(3).

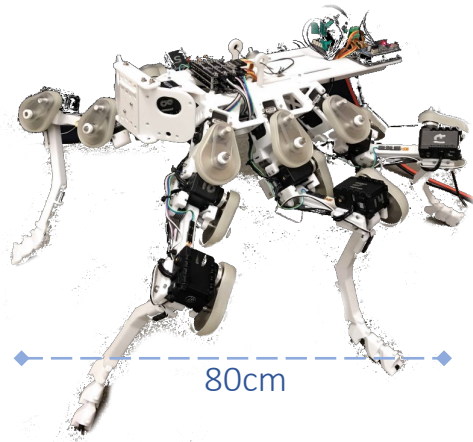
# Let's move on to hexapod robotics



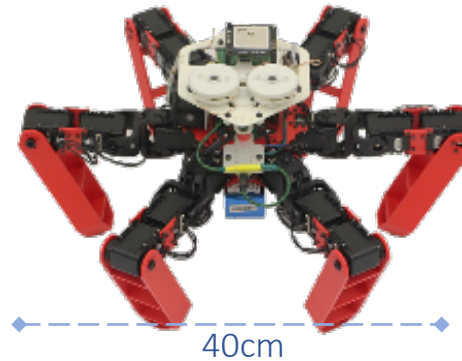
Julien Dupeyroux, Julien Serres, Stéphane Viollet (*Science Robotics*, 2019)  
[https://www.youtube.com/watch?v=YPvNVjrbDWM&feature=emb\\_logo](https://www.youtube.com/watch?v=YPvNVjrbDWM&feature=emb_logo)

# Rapid state-of-the-art in hexapods

Drosophibot<sup>[1]</sup>



AntBot<sup>[2]</sup>



PhantomX<sup>[3]</sup>



3DOF Phoenix<sup>[4]</sup>



Mass [kg]	1	2.3	2	1.3
Autonomy (approx.)	30min	15min	20min	20min
Joint speed [rpm]	59	90	106	50
Max charge (approx.)	700g	700g	700g	700g
Price	1k€	2k€	3,3k€	1k€

[1] Goldsmith C., Szczecinski N. and Quinn R., *Living Machines*, 2019.

[2] Dupeyroux J., Serres J. R., Viollet S., *Science Robotics*, 2019.

[3] PhantomX Metal Hexapod MK-III Kit, Ref. KIT-MKIV-XL-S, 2020.

[4] Barron-Zambrano, J. Hugo, Torres-Huitzil C., Girau, B, *Neurocomputing*, Volume 170, 2015.



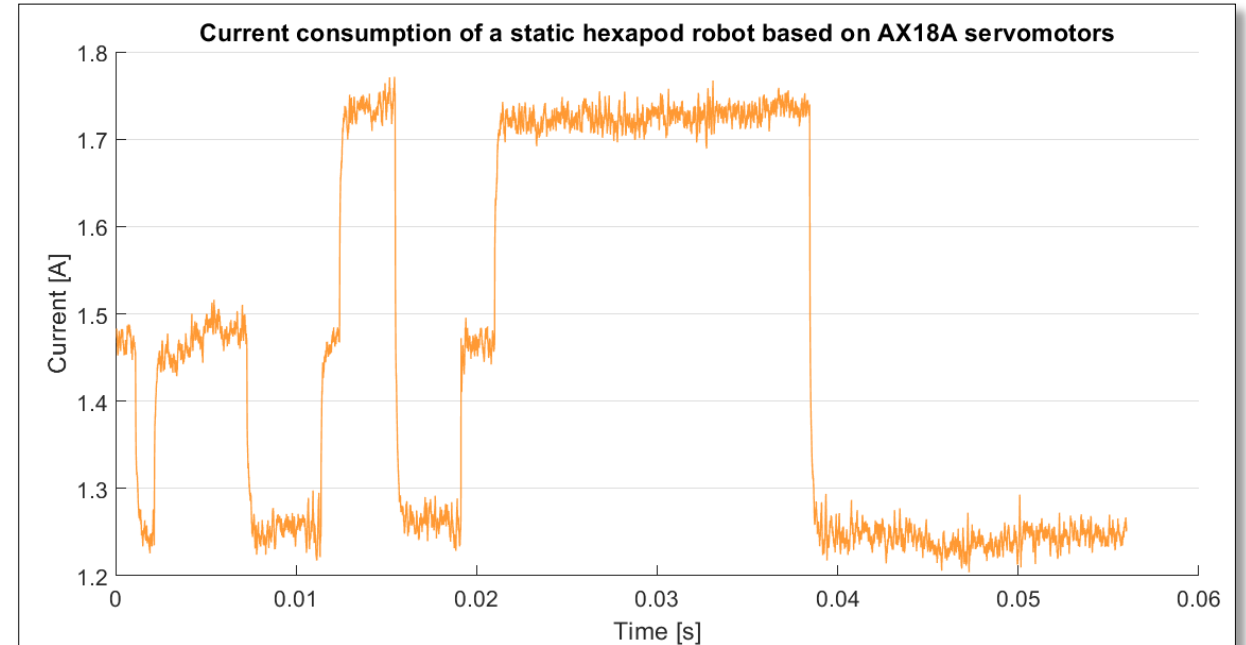
# Why servomotors are not well suited for locomotion?



Robotix Dynamixel AX18A

## Characteristics :

- Stall Torque 1.8Nm
- Speed 97rpm
- Price ~100€
- 54.4g



## Benefits :

- Simple to implement
- Precise control (speed, position)
- Compact
- Large choice of models

## Drawbacks :

- Overheating
- Weak gears
- Continuous power consumption
- High price

# Why servomotors are not well suited for locomotion?

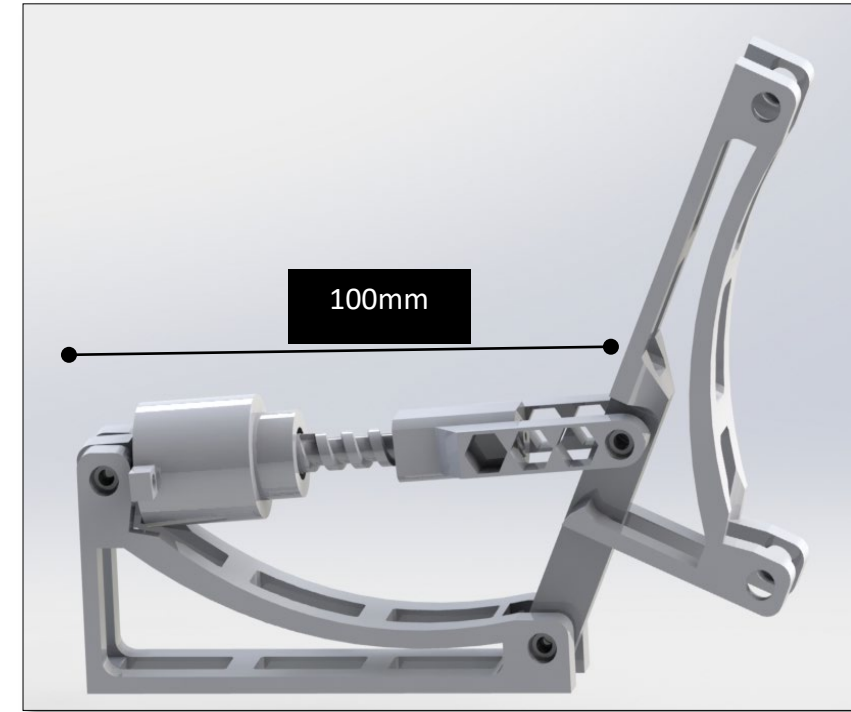


## Characteristics :

- Stall Torque 1.8Nm
- Speed 97rpm
- Price ~100€
- 54.4g

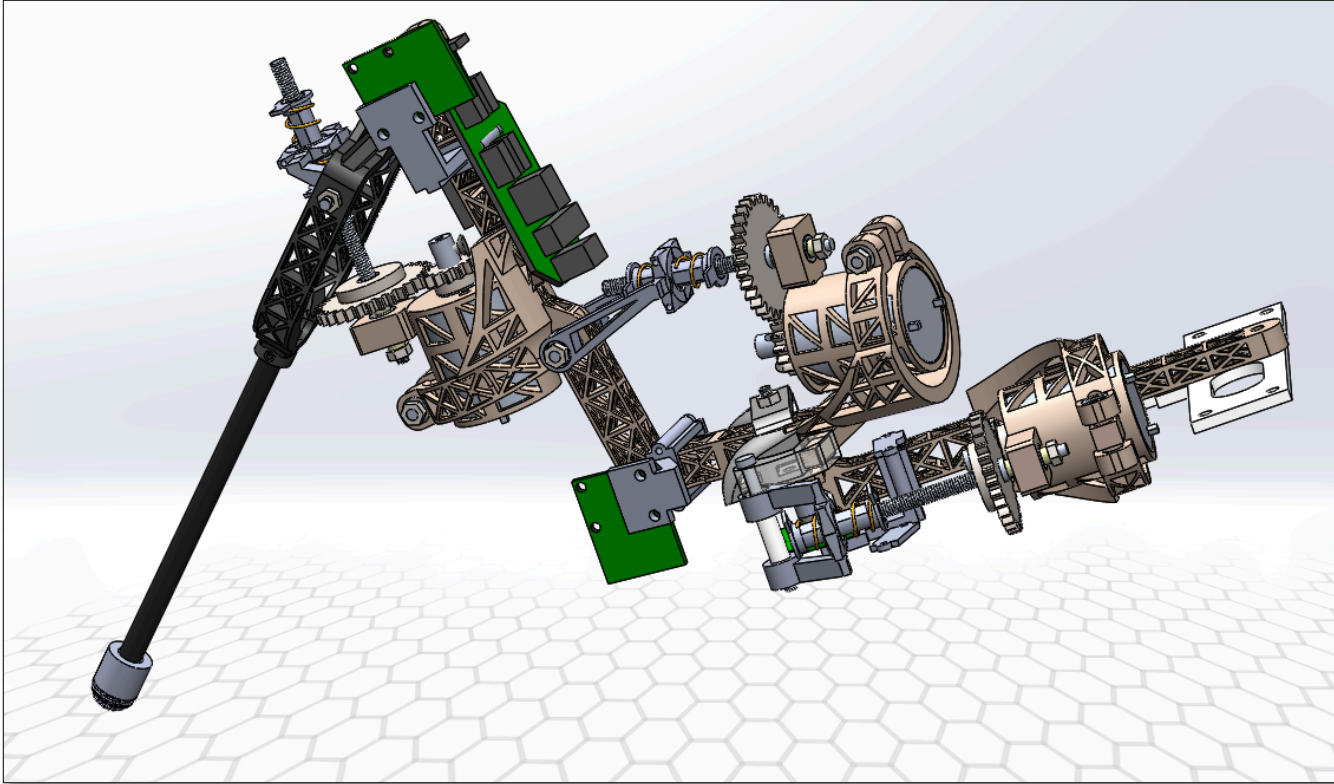
## Characteristics :

- Stall Torque 3.6Nm
- Speed 50rpm
- Price 20 ~ 50€
- ~ 110g



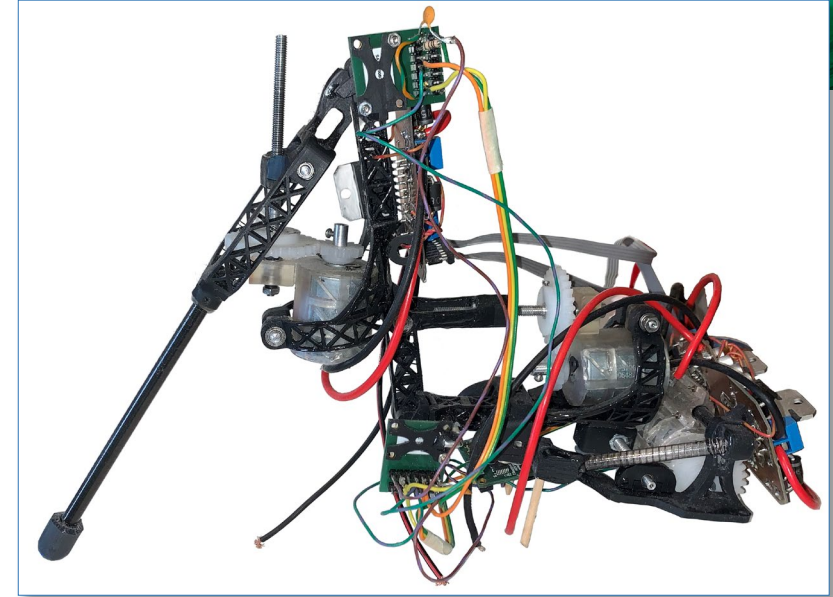
*Non-reversible actuated 3D printable joint*

# New compliant and non-reversible leg

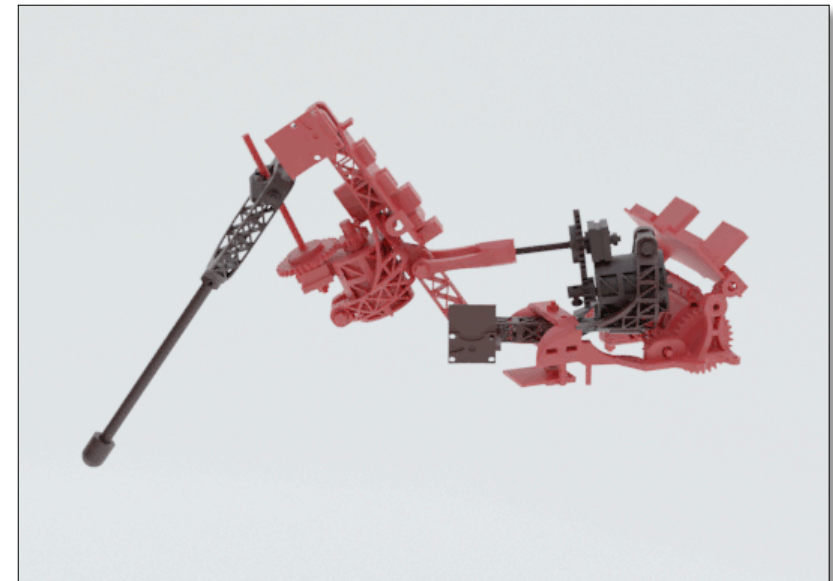


*CAD model of the new leg structure*

- 3 degrees of freedom per leg (walking only on a flat terrain)
- Angular & force sensors in joints (proprioception)
- Consistent dimensions with *Cataglyphis fortis* ant (scale 1:30)
- Fully 3D printed structure (easy to repair)



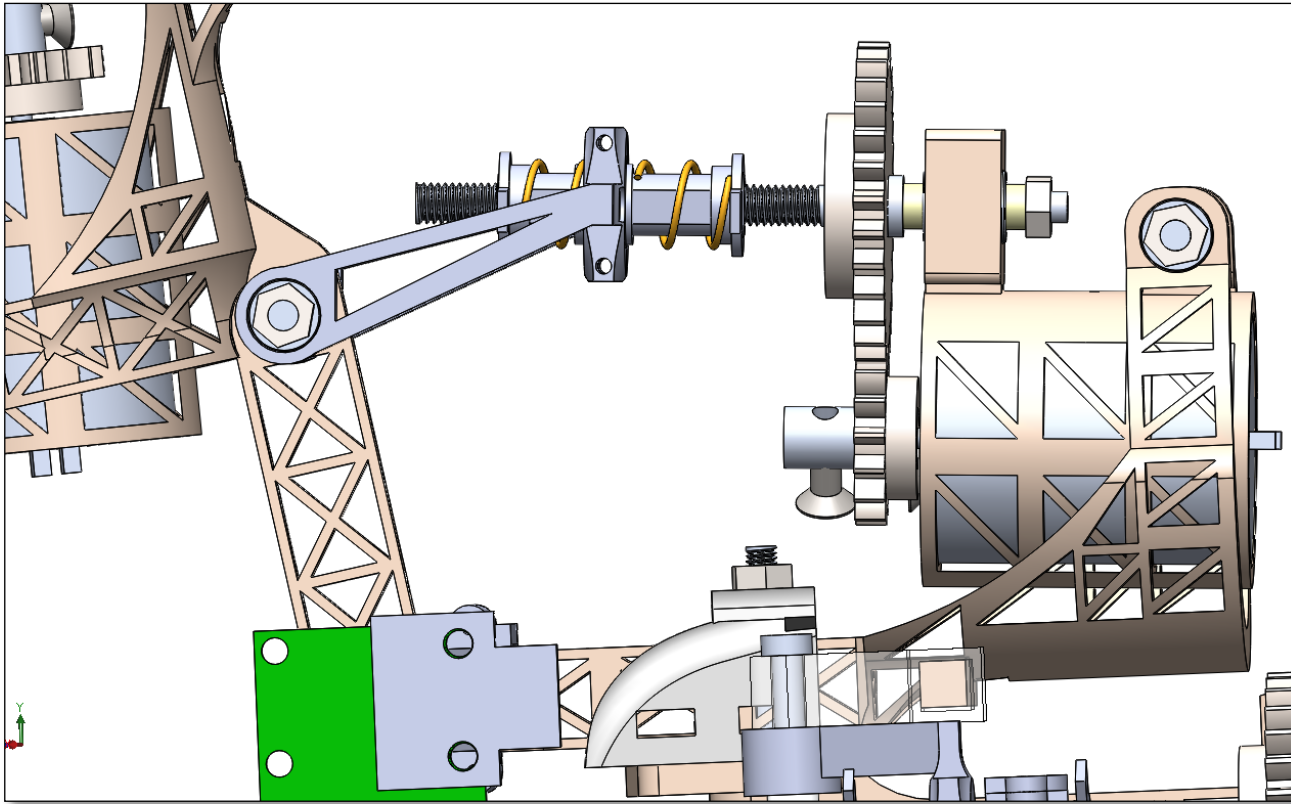
*Photography of the irreversible 3D printed leg*



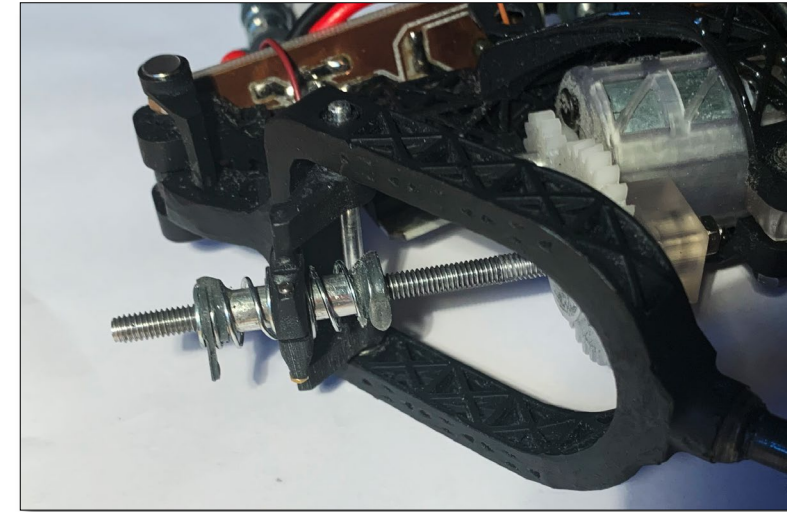
# Force sensing in the bio-inspired leg

Force sensor placement consistent with an insect leg

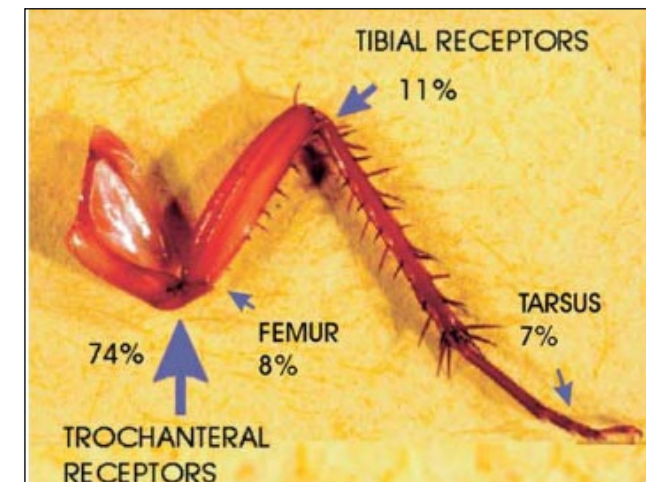
CAD model of the force sensor implemented on the leg



Photography of the force sensor



Distribution of *campaniform sensilla* on a cockroach leg

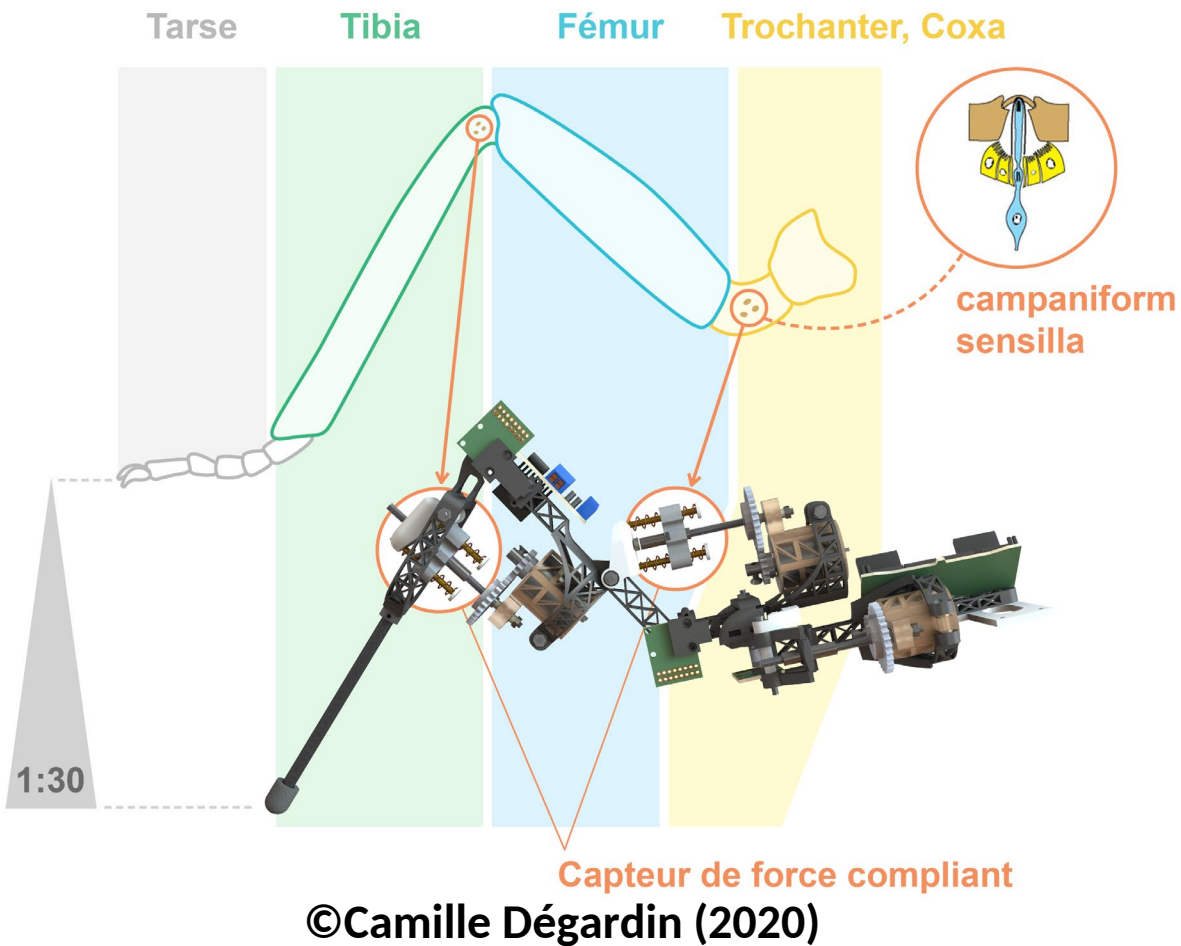


▲ Brodoline, I, Viollet S., & Serres JR. Full 3D printed hexapod robots with energy efficient joints. In : Workshop GDR 2088 BIOMIM 1st Annual Meeting, Nice, France. Oct. 2020, p. 33

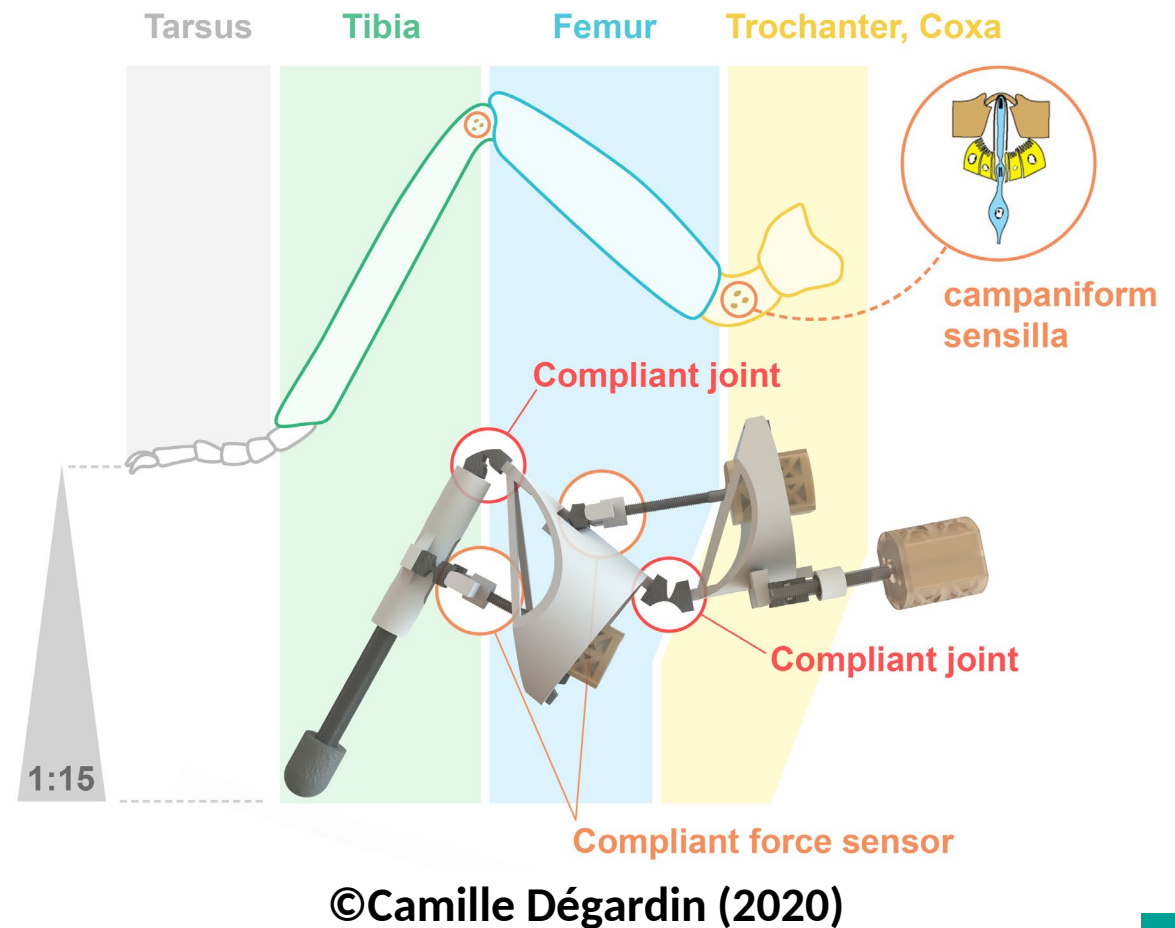
▼ Zill, S., Schmitz, J., & Büschges, A. (2004). Load sensing and control of posture and locomotion. *Arthropod structure & development*, 33(3), 273-286.

# Two new legs have been designed

## Non-reversible leg (Future hexapod Pohod15)

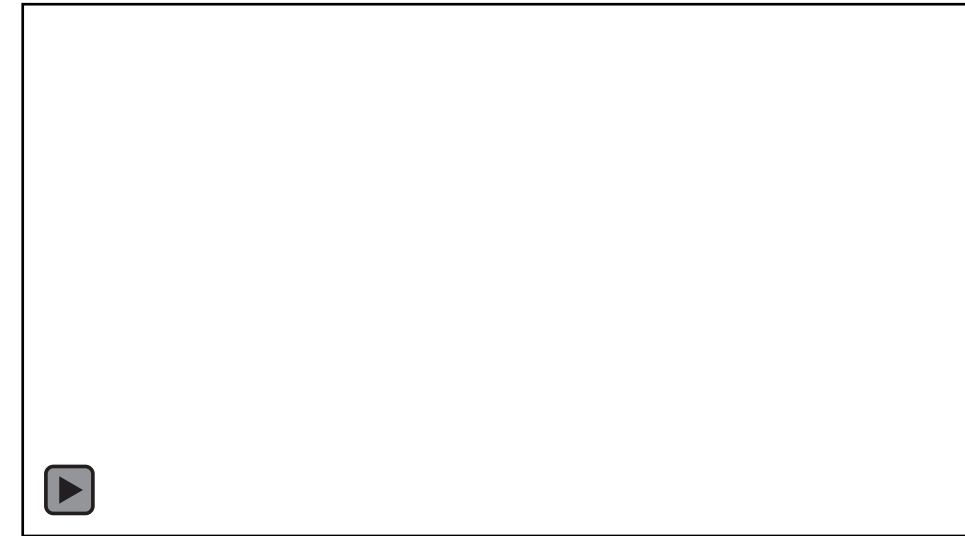
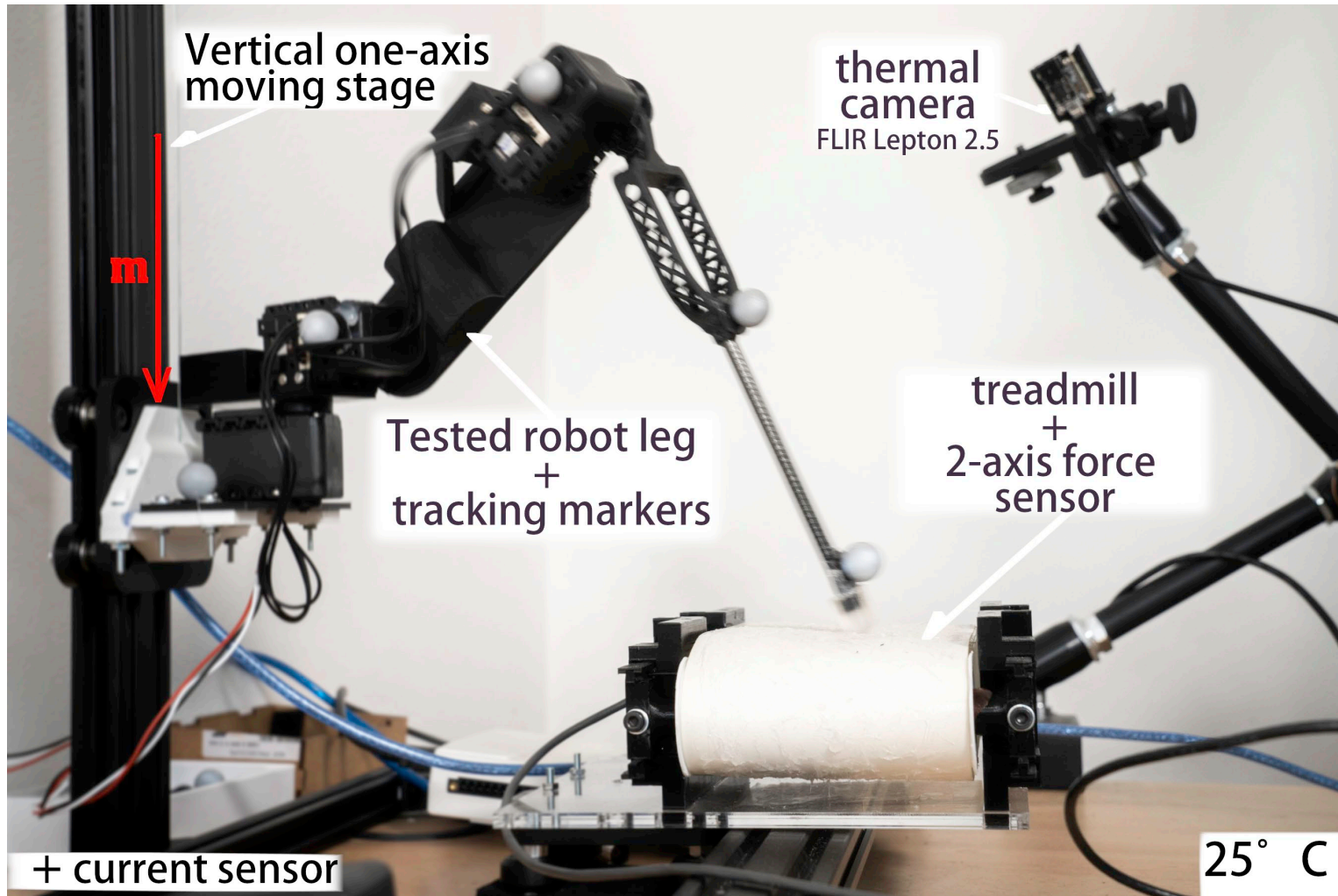


## Full 3D printed non-reversible leg (Future hexapod Pohod15J)



# The test bench built to evaluate legs

MiMiC-ANT test bench fitted with a QUALISYS motion capture system

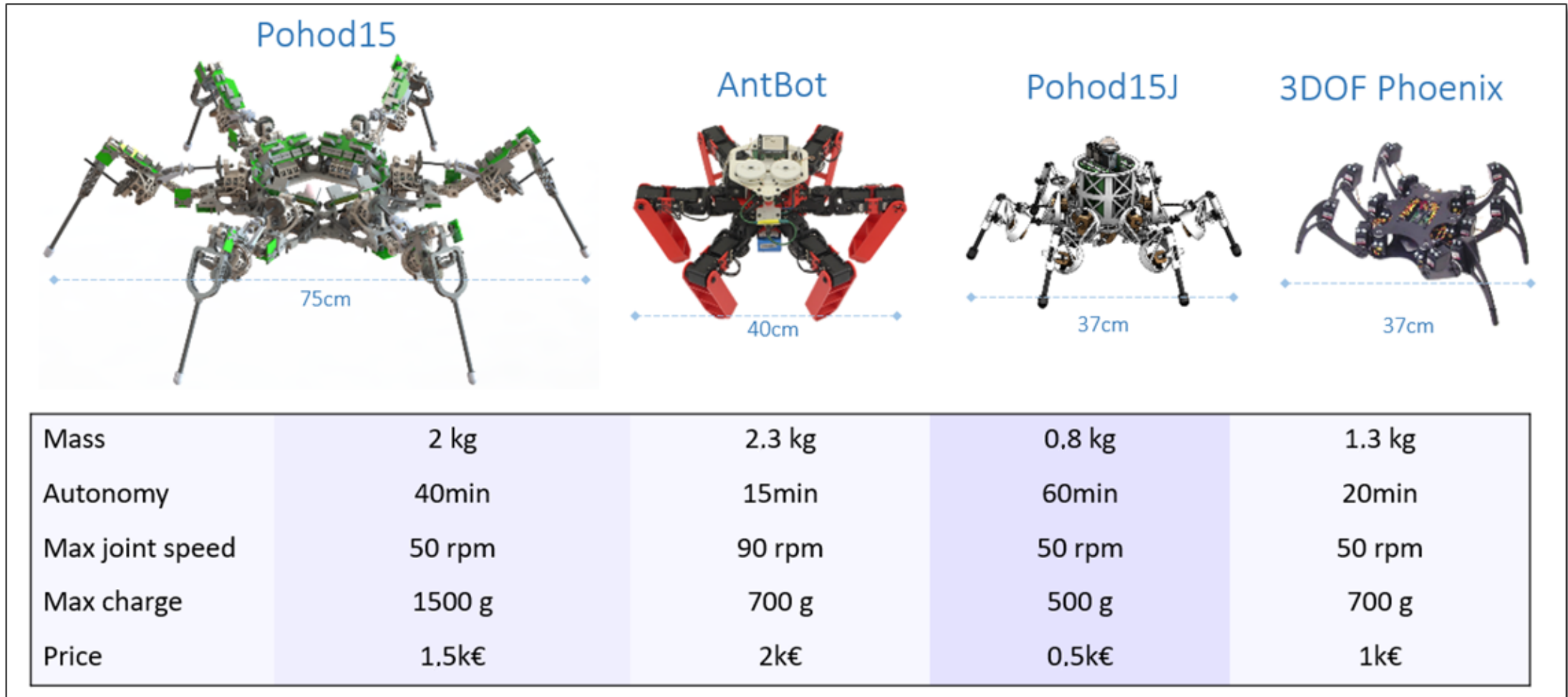


©Tifenn Ripoll - VOST Collectif / Institut Carnot STAR (2021)

see video « Nature = Futur ! Le Bio-Robot »

YT <https://www.youtube.com/watch?v=lqrLxtpk7YY>

# Expected level of performance of new hexapod robots (Pohod15 & Pohod15J)



▲ Brodoline, I, Viollet S., & Serres JR. Full 3D printed hexapod robots with energy efficient joints. In : Workshop GDR 2088 BIOMIM 1st Annual Meeting, Nice, France. Oct. 2020, p. 33

# Conclusion and future works

- The **MiMiC-ANT project** has allowed us to better understand the gap between hexapod robots and ants (*legs morphology, force sensing, legs coordination, and cost of transport*).
- An experimental set-up has been developed to understand the load transport in ants.  
**Ants adjust their locomotion gait pattern while transporting a load.**  
A set-up to measure **ground reaction force in ants** is in development **in 2021-2022**.
- Two kinds of legs **comprising non-reversible joints and force sensing** have been built.  
The expected levels of performance should be **at least twice better** w.r.t conventional leg.
- A **MiMiC-ANT test bench** has been built to evaluate benefits of the new bio-inspired legs with respect to a conventional leg design **in 2021**.
- **Building the two hexapod robots** (Pohod15 & Pohod15J) will be the next step **in 2022** to mimic locomotion pattern adjustments observed in ants while transporting a load.