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BirdBot achieves energy-efficient gait with minimal control using avian-inspired leg clutching

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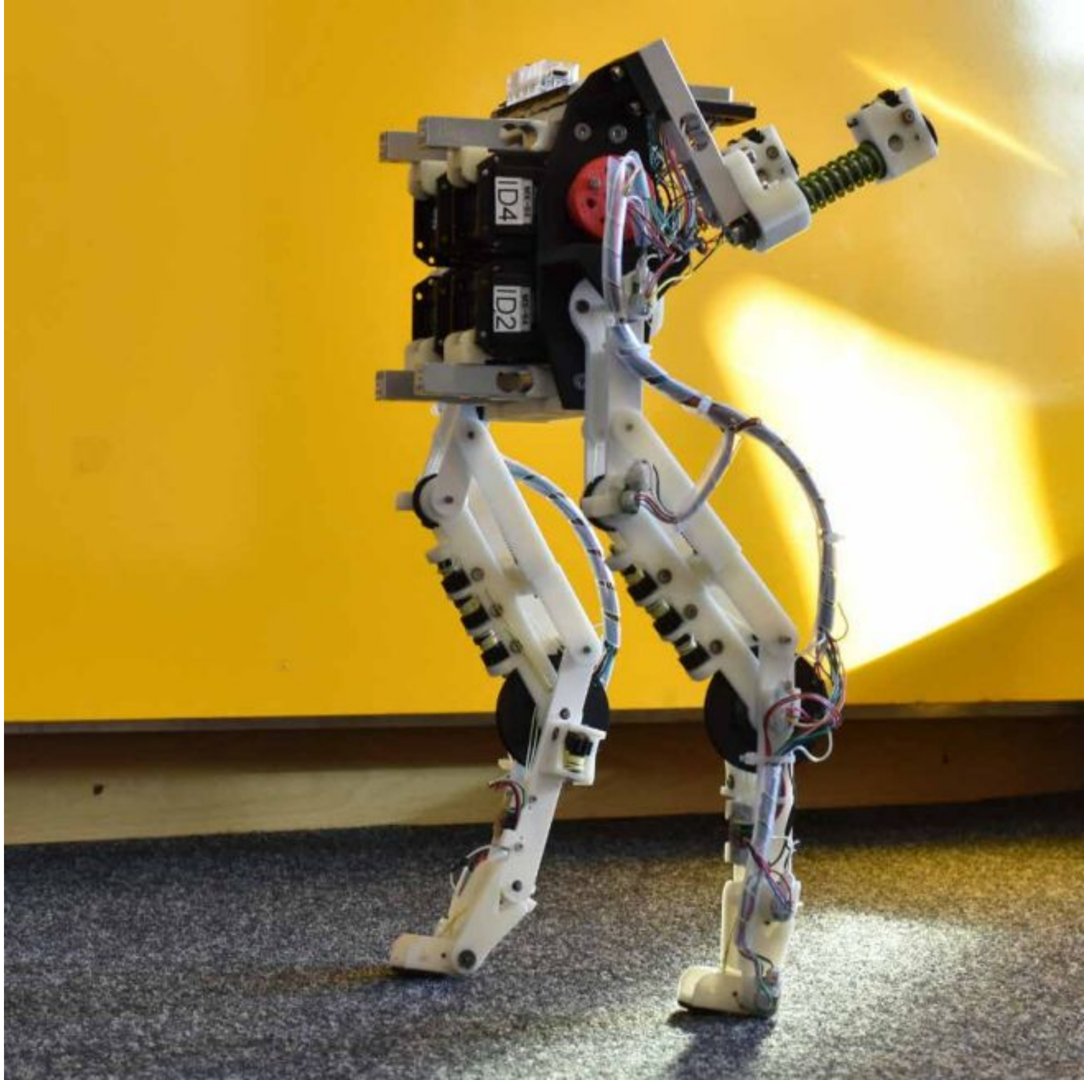
Why BirdBot ?

- Energy efficiency with minimalistic and robust control
- Challenge to be met : legged robots vs terrestrial animals
- Dependency on high quality sensors and high speed communication vs intrinsic mechanical coupling



Biological inspiration

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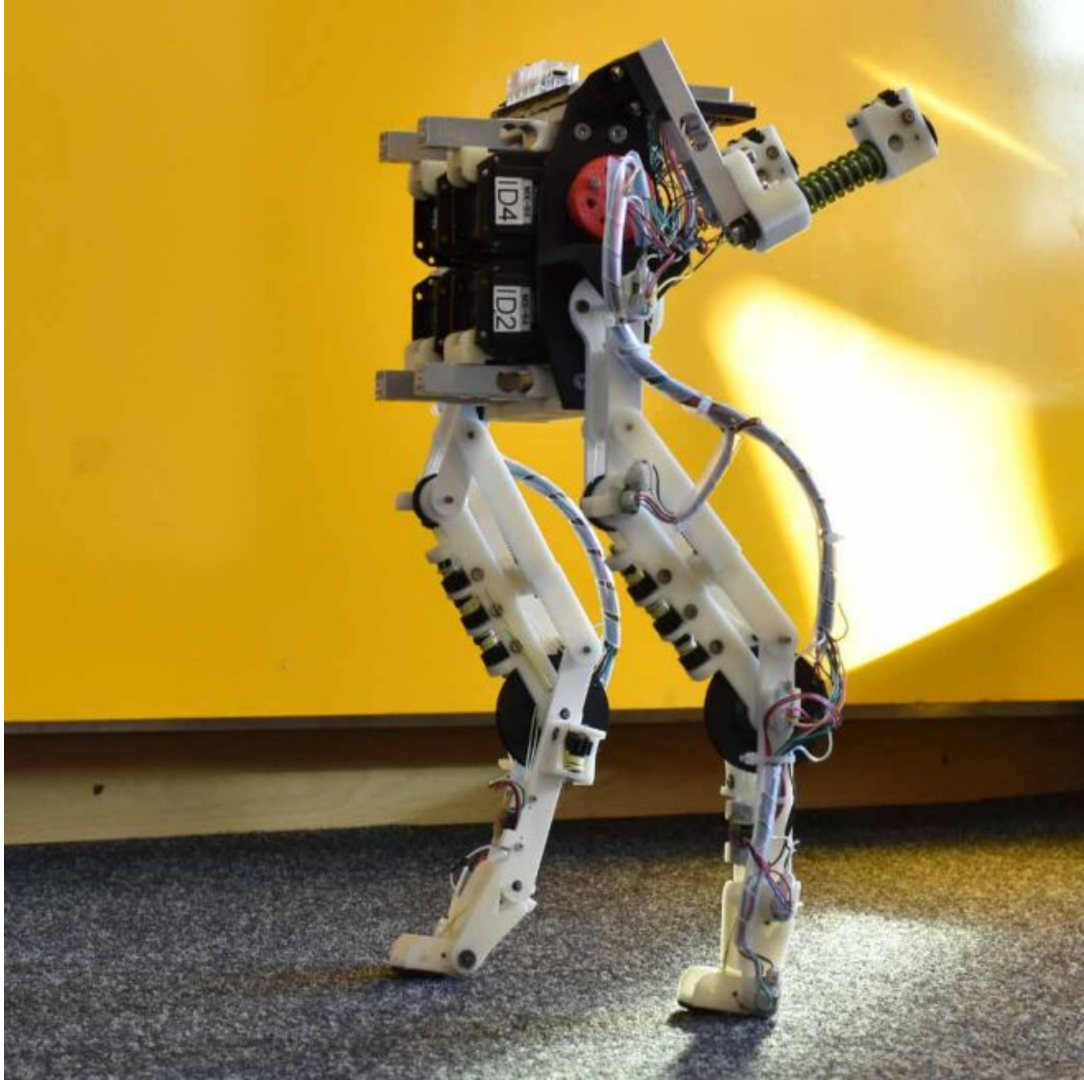
What is BirdBot ?

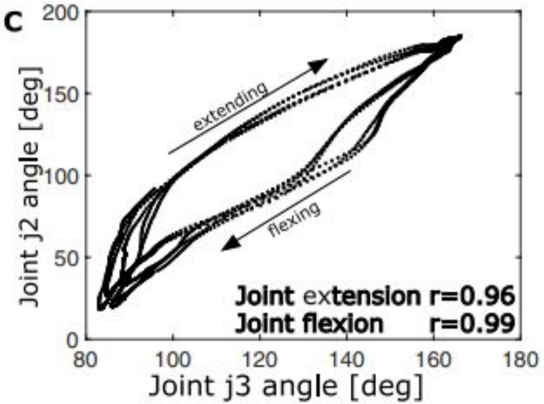
- Biped, planar, bio inspired robot
- Inspired by large ratites (emu,ostrich)
- Foot contact based leg spring clutch
- Four actuators total : two per leg (hip and knee) → underactuated
- Control : Feedforward by a CPG
- No sensory feedback
- Gait emerges from mechanics + CPG, not explicitly commanded

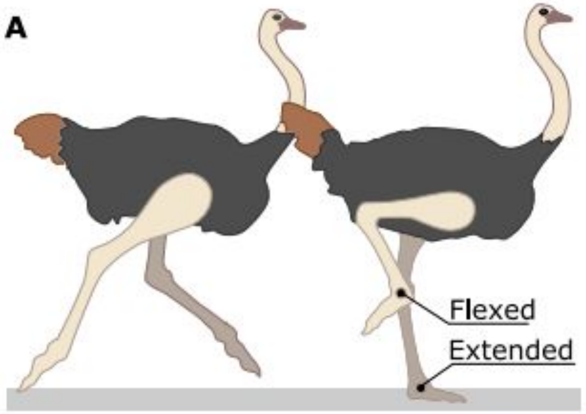


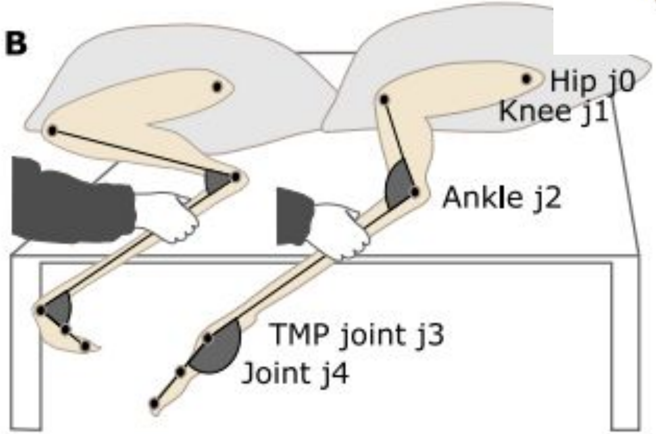
Global functioning of the robot

What’s so special with the birds leg structure?

- Ratite legs show passive tissue coupling
- The coupling is due to passive tissues (tendons, ligaments, fascia), not active muscle control.







How Birdbot implements it (1/2)

In Ratites:

- A single tendon runs through multiple joints and coordinates their motion

In the model:

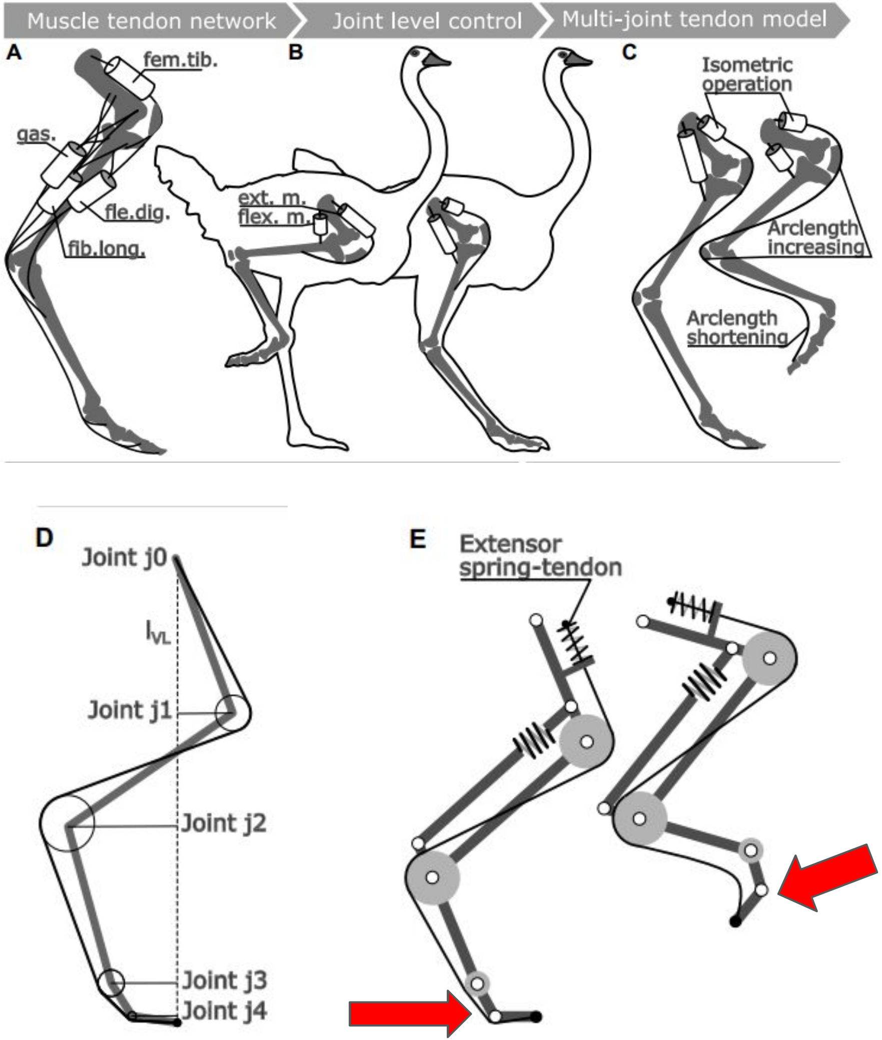
- Each biological articulation is replaced by a pulley.
- A single tendon, the GST, runs through all pulleys.
- The tendon is attached to a spring at the end.

When the leg touches the ground:

- The foot is pushed into extension, which compresses the spring

When the leg is lifted:

- The foot moves back, the tendon shortens which decompresses the spring.



How Birdbot implements it (1/2)

Knee tendon (Blue):

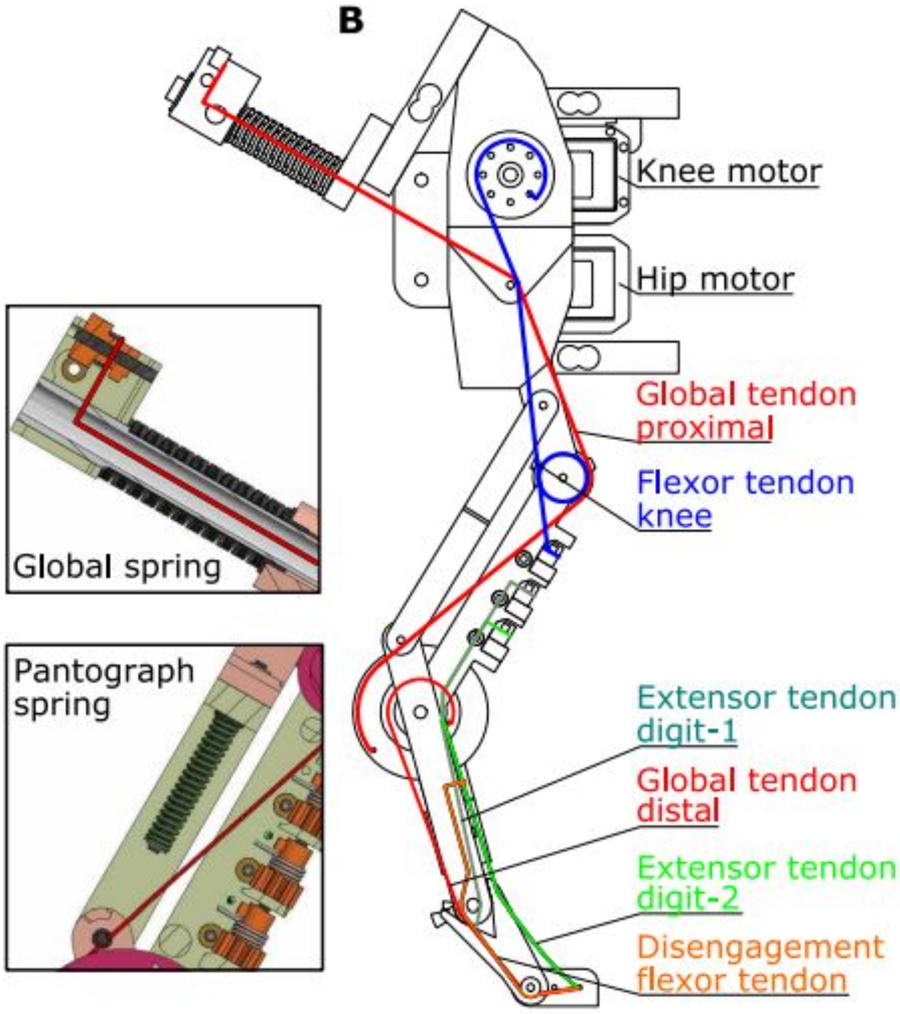
- Connects the knee motor to the knee joint.
- Allows the motor to influence and coordinate the rest of the leg.

Digit extensor tendons 1 & 2 (Green and turquoise):

- Help control the foot and the joint just before it.
- Provide more stable articulation of the lower leg.

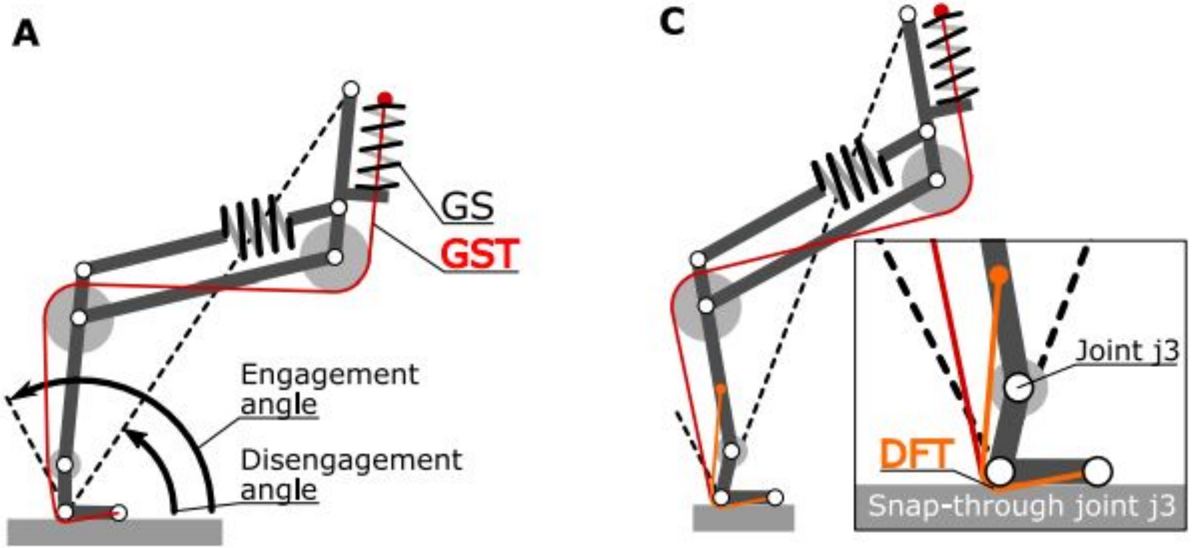
Disengagement tendon (Orange):

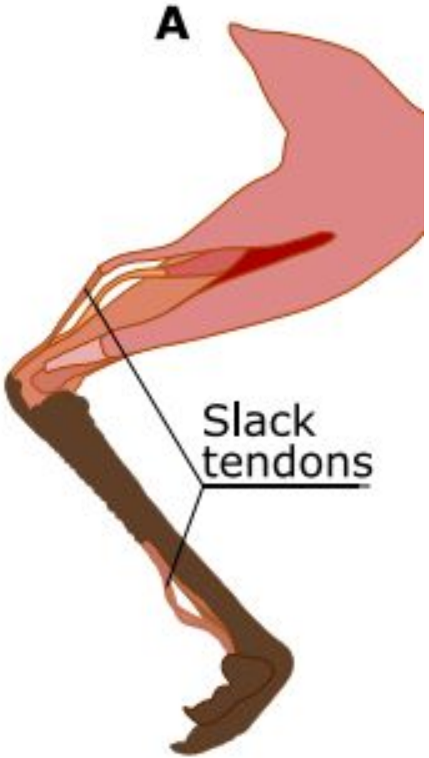
- Enables the foot to return from an extended position to a flexed one.



Zoom on the disengagement Tendon

- Results in a much tighter disengagement angle.
- This angle occurs earlier in the movement compared to systems without this tendon.
- Design is inspired by the slack tendons found in ratites (e.g., ostriches, emus).





How does Birdbot implement it?

When the leg is extended on the ground:

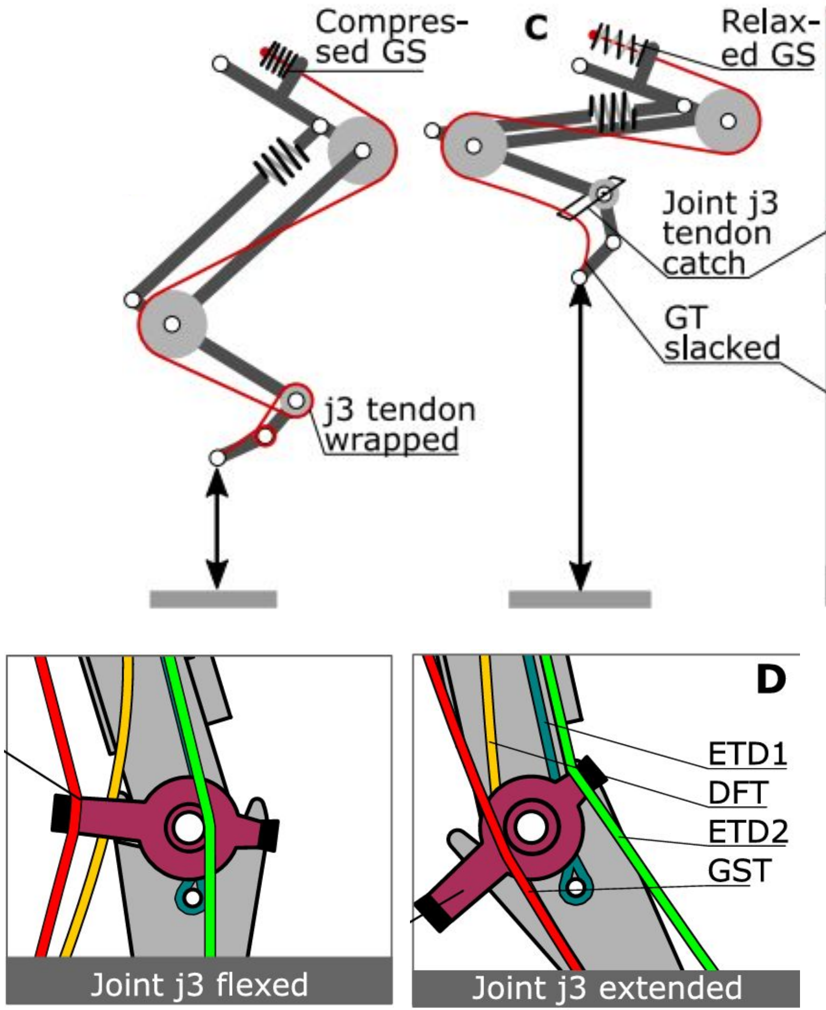
- The tendon is pressed tightly against its pulley.

When the toe lifts off the ground:

- The tendon snaps off the pulley, allowing the GST to rapidly loosen, enabling the leg to flex efficiently during swing.

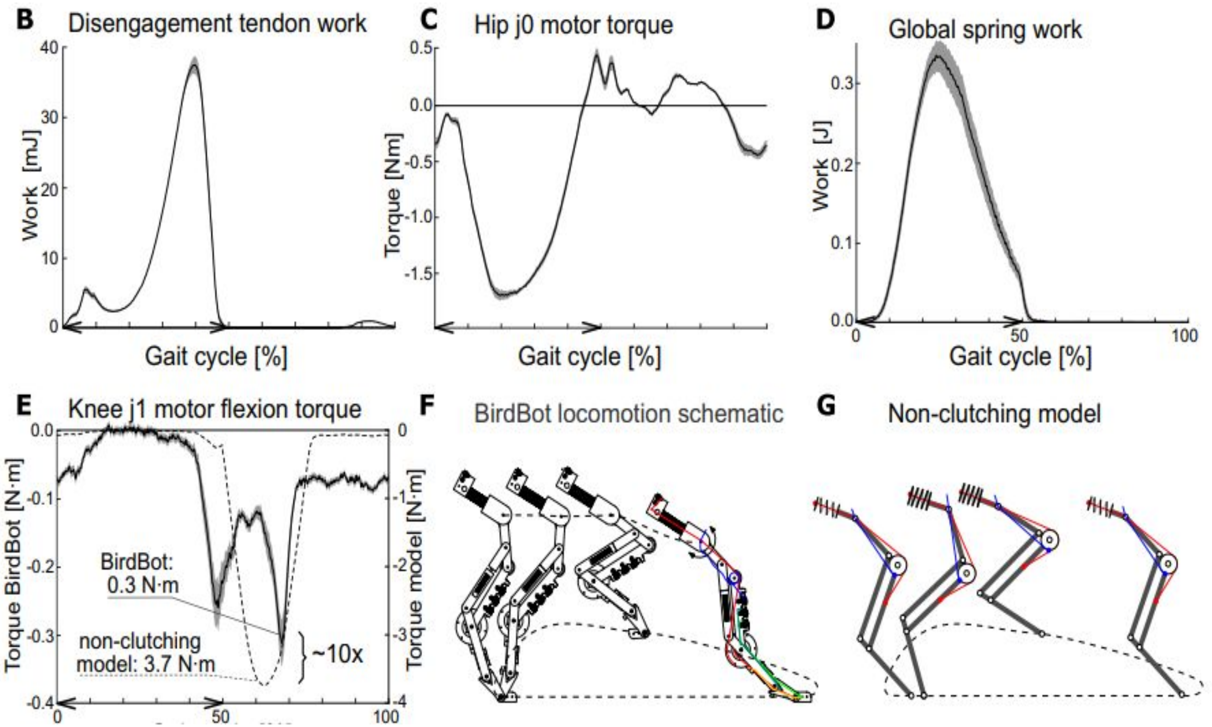
To prevent tendons from flapping or getting tangled:

- A tendon catch is added.
- It guides and constrains both the GST and the disengagement tendon.

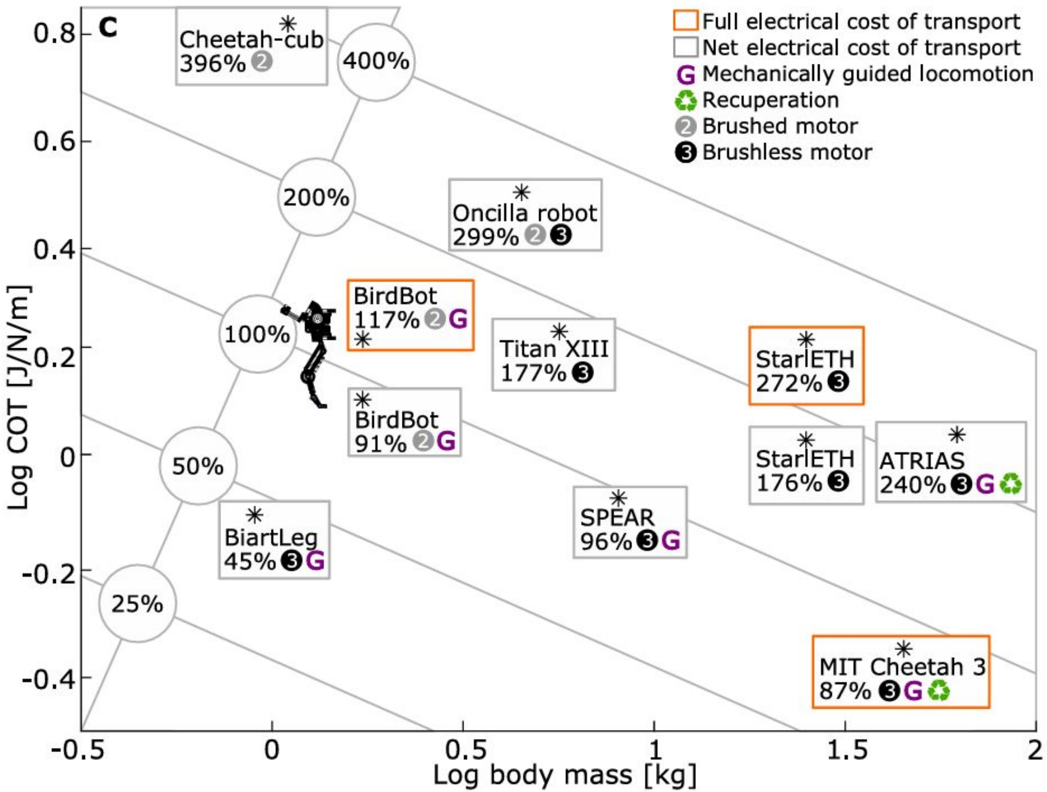


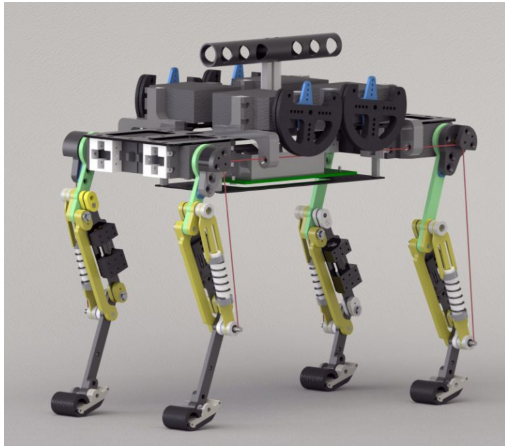
Results

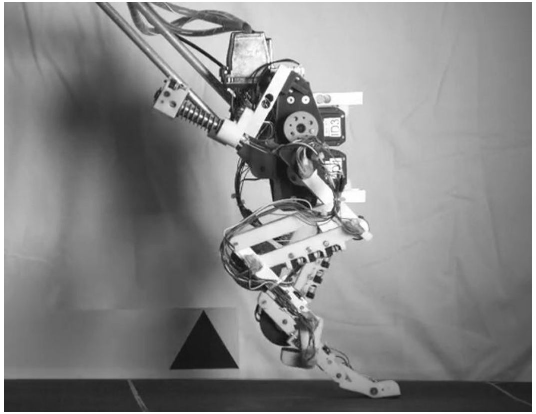
- The bistable mechanism rapidly releases tension once the foot leaves the ground.
- The coupled tendon system supports the leg passively while on the ground.
- Greatly improves energy efficiency of the gait cycle.



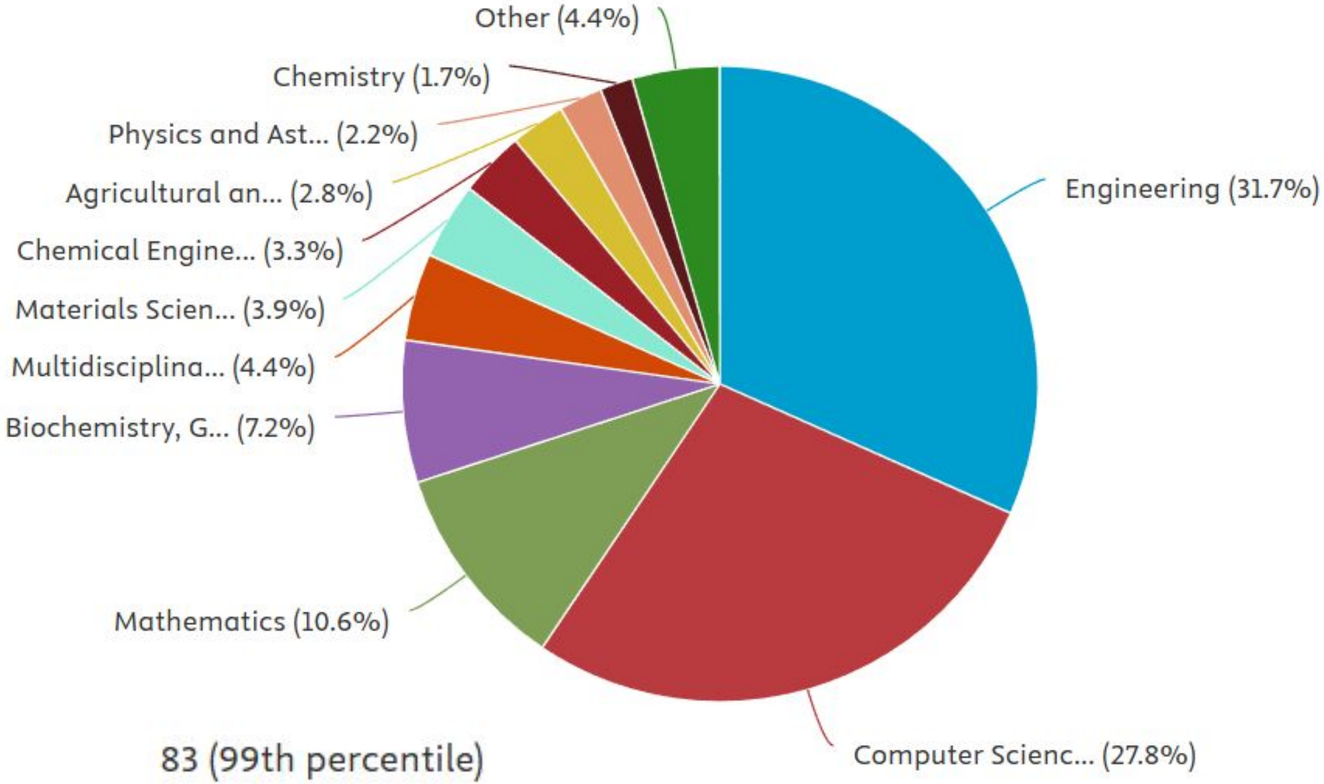
Birdbot’s efficiency







Citations



Citations	83 (99th percentile)
Field-Weighted citation impact	11.43

er considerable force"[39]. Badri-Spröwitz *et al.* show tendon slack in the flexing motion of
gits of large birds, and implement tendon slack in the related robot[41]. By disengaging

., 2001). Among these, BirdBot is particularly interesting,

e had hypothesized that GST would have a similar function as in BirdBot [25]

d the same design principles as BirdBot [25], determining the pulley radii via
e mechanical advantages (EMA) [38] in standing position to create a leg that
anding. The coupling kinematics of the extensor tendon in the power phase ca
om the ankle to a digit joint with the transmission ratio n_j:

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with small stiffness in the flight phase. Although BirdBot [12] performs excellent energy-efficient gait the design of the spring tendon network is complicated, which may hinder its applicability in legged robots. Accordingly, designing a simple but effective decoupling mechanism to achieve an energy-efficient legged robot is needed.

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PROS	CONS
Energy efficient (COT comparable with natural runner)	Limited terrain adaptability (sensitive to uneven ground)
Low joint torques	Timing sensitivity of stance-swing transition
Minimal Control (feedforward, CPG, no sensor feedback)	Not free standing in 3D (needs lateral stabilization)
Passive phase switching (bistable toe joint triggers stance-to-swing)	Lacks agility, cannot rapidly change gait, speed or direction
Mechanically stable, scalable in size	Complex mechanism that requires fine tuning
Multiarticular tendons distribute load efficiently	Difficulty to replicate mechanism

THANK YOU ! ANY QUESTIONS ?