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erc Advanced Grant

Small-Scale Bipedal Platform with Tail for Winged Aerial Robots

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1. Introduction

- Motivation for the development of flapping-wing platforms:
  - Energy efficiency compared to multi-rotors.
  - Safety in close interaction with humans.
- Abilities of these platforms: gliding, perching, manipulating.
- Some illustrative application examples:
  - Assistance to injured people (delivery of medicines, measurement of pulse-oxygen) in remote areas like mountains.
  - Taking samples in extensive fields: vine, grain, water…
  - Inspection of vast infrastructures (power lines) with contact sensors.
- Usual approach in aerial manipulation with multi-rotors:
  - ❖ Operation carried out on flight.
  - ❖ Exploiting the high maneuverability of the multirotor.
- Winged aerial robots need to perch or land before manipulating.

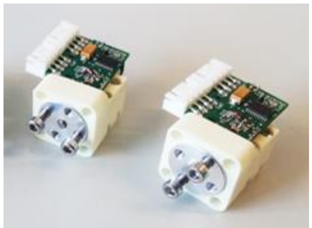
1. Introduction

- Winged aerial robots need to perch or land before manipulating:
  - ❖ Limited displacement of the platform once this lands → positioning problem.
  - ❖ The impulse and initial velocity required to fly reduces the access to workspace.
- ✓ Solution: development of bipedal locomotion capability for winged aerial robots.
- Contribution of the paper:
  - Mechatronic design of small-scale (0.16 cm) and lightweight (0.6 kg) robotic legs (2-DOF per leg) with tail (pitch/yaw) intended for perching and walking.
  - Modular design approach: Maxon-Harmonic Drive industrial-grade actuators.
  - Customized control electronics allowing torque/speed/current control.
  - Experimental validation:
    - Perching on cables using the tail to maintain equilibrium (AERIAL-CORE).
    - Manipulating with one leg while the other is used for perching.
    - Preliminary walking tests using the tail in yaw for counteracting.

2. Robot design - Actuators

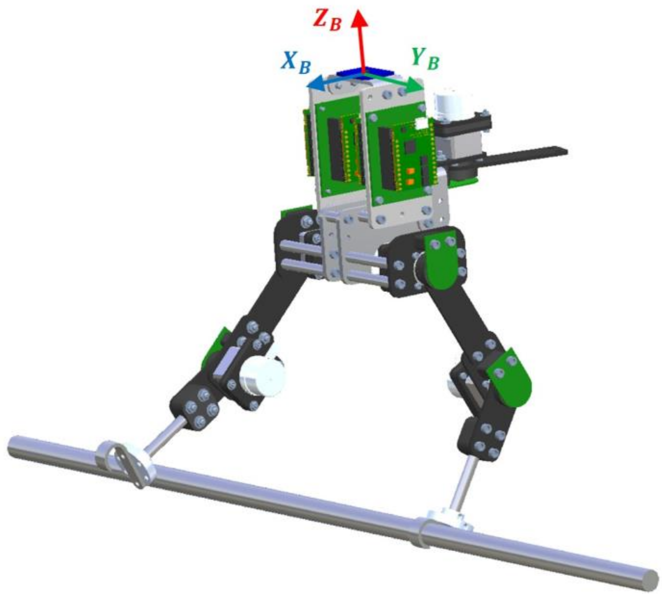
- Comparison of actuators:
  - Herkulex DRS-0201
  - Pololu micro-servos
  - Maxon-HD
- Maxon-Harmonic Drive:
  - Very high performance
  - Zero backlash
  - High axial/radial/tilting load
  - Speed/current (torque) control

Actuator Features	Herkulex DRS-0201	Micro servo	Maxon-HD
Weight [grams]	60	25*	70*
Reduction ratio	1:266	1:250	1:100
Max speed [rpm]	68	120	150
Stall torque [Nm]	2.4	0.34	-
Rated torque [Nm]	~0.6	~0.2	0.6
Peak torque [Nm]	-	-	1.4
Update rate [Hz]	50	200	200



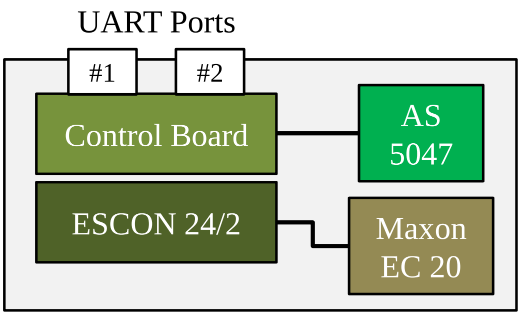
2. Robot design - Prototype

- Legged platform with tail.
- Total weight: ~0.6 [kg]
- Legs size: 160 [mm]
- 2-DOF per leg: hip & knee.
- 1-DOF tail:
  - Pitch config for perching
  - Yaw config for walking.
- Frame struct: CF + AL + PVC
- Integrated control electronics:
  - Maxon ESCON 24/2
  - Customized control board
- IMU for orientation meas.



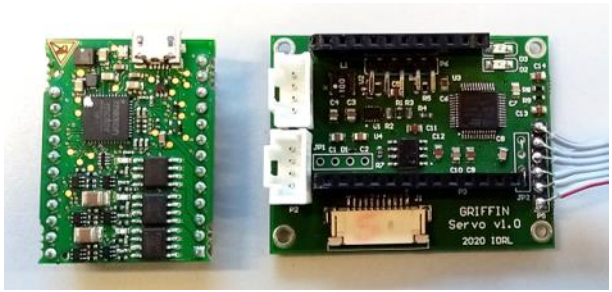
3. Electronics

- Three components:
  - Maxon ESCON 24/2: low level control (speed/ current) of the Maxon motor.
  - Customized control board (Ivan Diez): position controller, interfacing the ESCON and magnetic encoder with the main computer.
  - Magnetic encoder AS5047: absolute position measurement of the output link.



Magnetic encoder

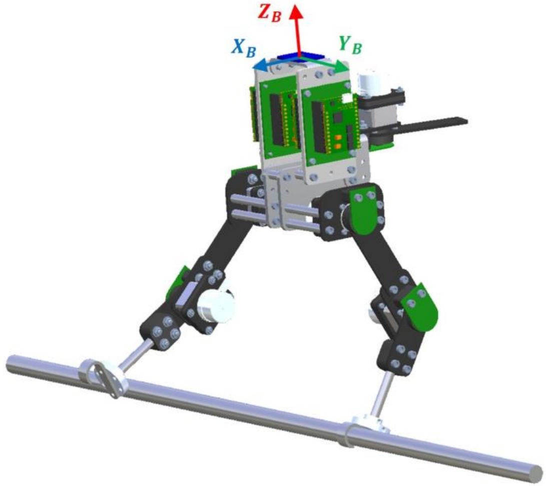
Motor flex-PCB connector



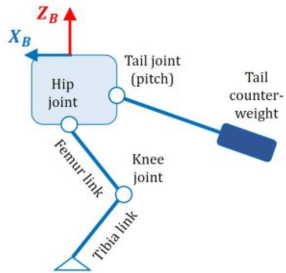
Maxon ESCON 24/2

Customized control board developed by Ivan Diez

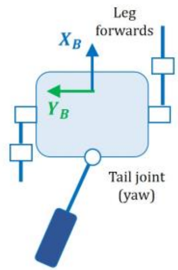
4. Modeling and control



- Definition of kinematic model for perching and manipulating with one leg.
- Control modes: position (PID) / speed / torque.
- Control feedback:
  - Body orientation (IMU) measured at the head
  - Joints position (encoder) and speed/torque (ESCON 24/2)
- Use of the tail as counterweight to maintain the equilibrium while perching and to counteract the yaw-moment when walking.
- Preliminary studies on walking in testbed.
- Possible study of hopping using springs.



Tail in pitch configuration for perching



Tail in yaw configuration for walking