Small-Scale Bipedal Platform with Tail for Winged Aerial Robots

Alejandro Suarez, Ivan Diez de los Rios
GRVC Robotics Labs – University of Seville
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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 it lands $\rightarrow$ 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

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