Autonomous untethered flight of multibody dynamics rotorcraft with cycloidal rotors

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Louis Gagnon & Pierangelo Masarati

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Outline

- **Introduction**
  - project objectives, studied aircraft, cycloidal rotors
- **Modeling**
  - multibody architecture, control algorithm, optimal tuning
- **Results**
  - path following, energy consumption

Objectives

- **Develop untethered aircraft models**

  - traditional helicopter

  - “Quadricyclogyro”
    - *a quad cycloidal rotor aircraft*

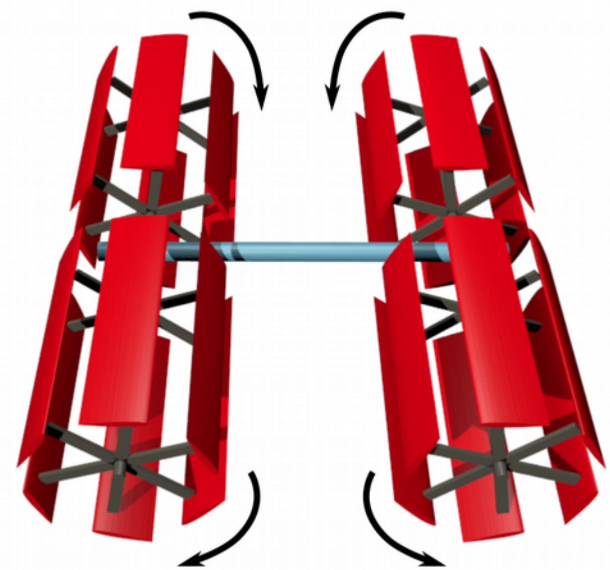
  - “Heligyro”
    - *a compound helicopter w/ cycloidal rotors*

Studied Rotorcraft

Helicopter

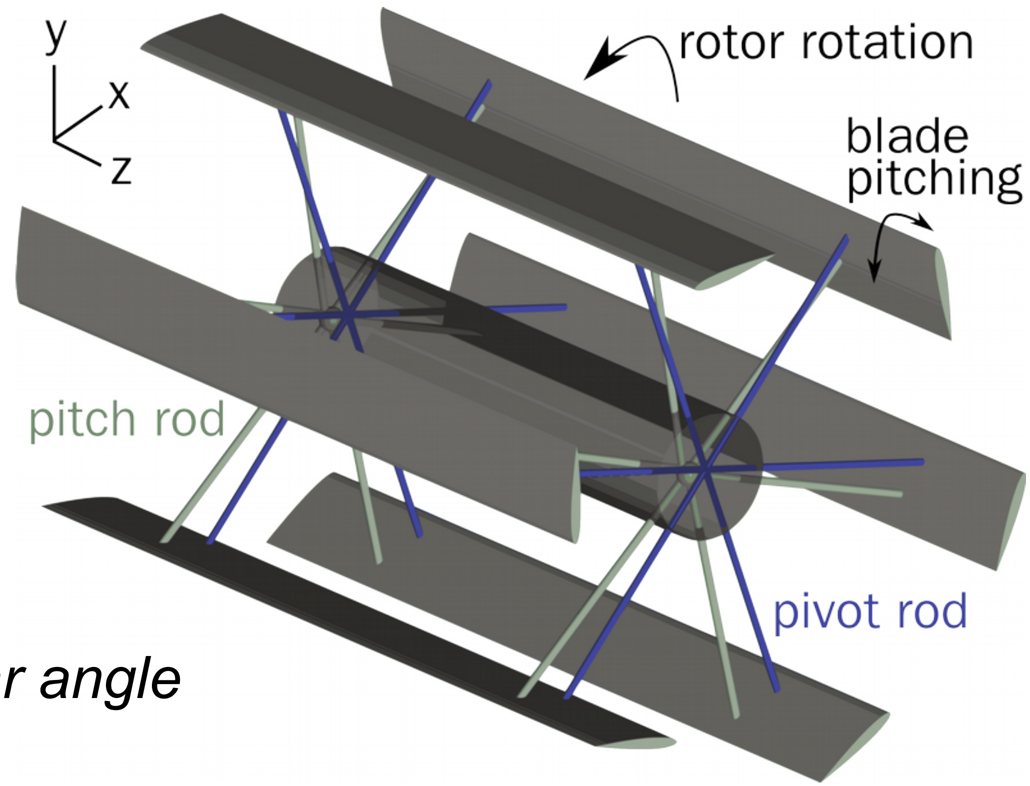
Heligyro

Quadricyclogyro



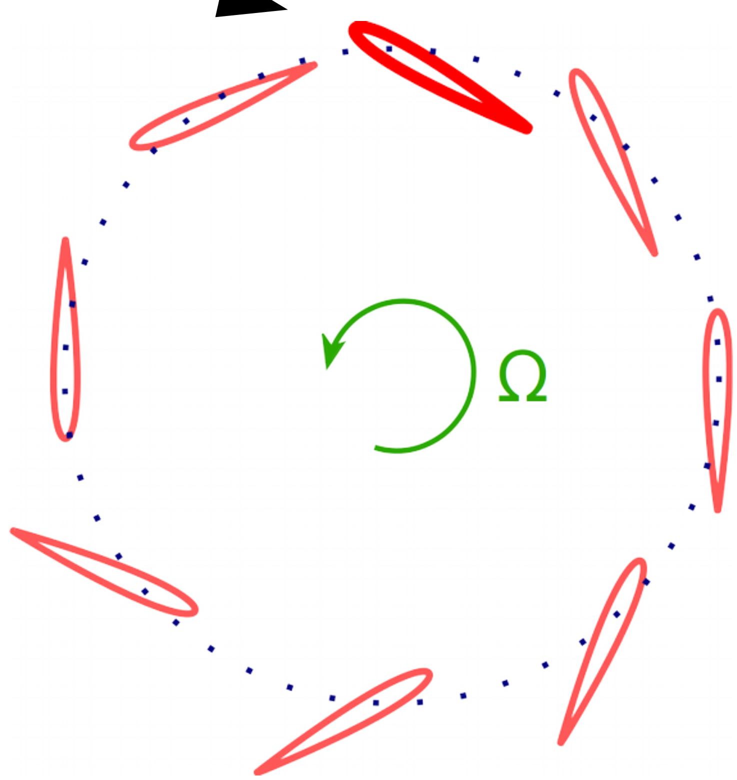
Cycloidal Rotors

- **Century old concept**
  - airborne:
    - *only exist as prototypes*
  - water:
    - *tug boats and ferries*
  - advantages:
    - *directional thrust*
    - *cost. span airspeed*
    - *allows flight at any planar angle*



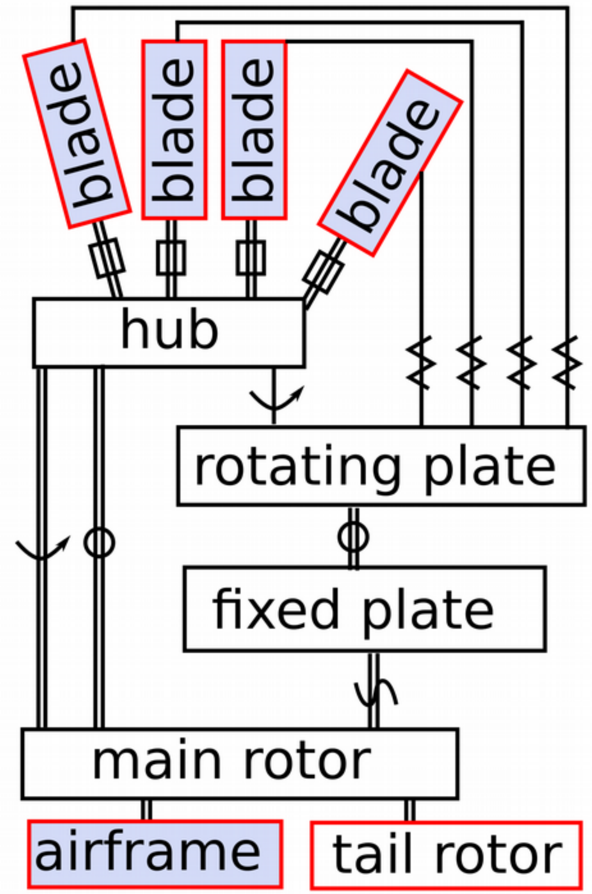
Follow a Blade over a Single Period

- **Can pitch harmonically**
  - about its pivot axis
    - *ex: 30 sin(Ω t) degrees*
  - ...and rotates about rotor's center
- **Consequently,**
  - generates:
    - directional thrust
    - inflow
    - rotation resistance (drag)



Bo105 Helicopter Multibody Model

- **Implemented in MBDyn**
  - only rigid elements
  - aerodynamic elements for rotor blades
    - *with twist*
    - *based on lookup-table*

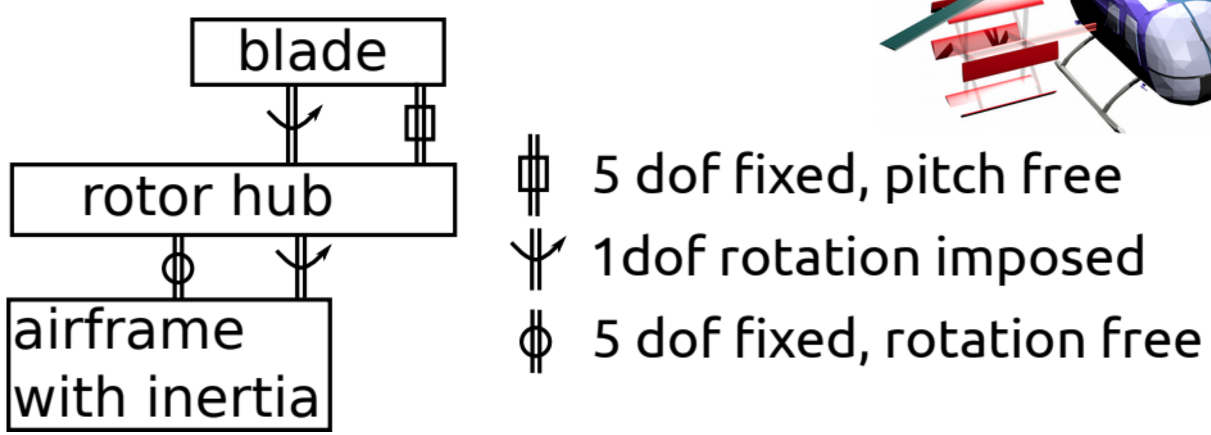


Legend

- 5 dof fixed, pitch free
- 3dof control, 3 dof fixed
- 1dof rotation fixed
- 1dof rotation imposed
- rigid connection
- node
- with intertia
- aerodynamic force
- viscoelastic rod
- 5 dof fixed, rotation free

Cycloidal Rotor Multibody Model

- **Simple arrangement of blades**
  - rotate about central drum
  - controlled harmonic pitching about pivot
  - custom 1D inflow model



Control Algorithms

Each aircraft controlled by similar PIDs

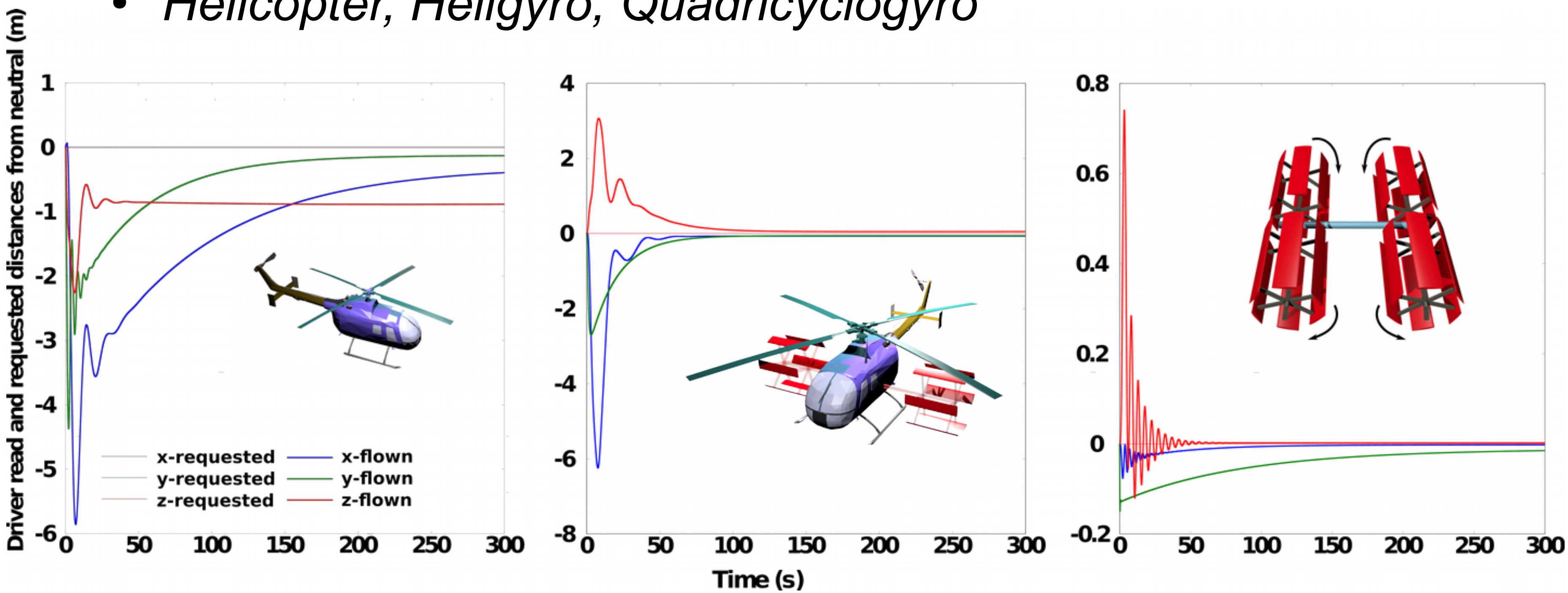
- dynamically adjust control surfaces
- *controller input signal is error at current timestep*
  - *btwn filtered 6D position and requested path*
  - work in both in translation and rotation
- Helicopter and Heligyro have simple Stability Augment. Syst. (SAS)
- Quadricyclogyro:
  - ***forward/rearward/yaw*** *obtain by controlling blade pitch functions*
  - ***roll/pitch*** *obtained by differential L/R or F/A rotor pitch functions*
- Heligyro:
  - *controls* ***yaw*** *by differential long. thrust of cycloidal rotors*

Tuning the controllers

- **Controllers tuned by path error minimization**
  - Single-objective Genetic Algorithm (SOGA)
    - *28 to 32 optimization variables*
    - *using flight time between 2 and 5 minutes*
    - *minimizing energy consumption*
    - *minimizing cabin vibrations*
    - *ran with MPI for many-task computing (MTC)*

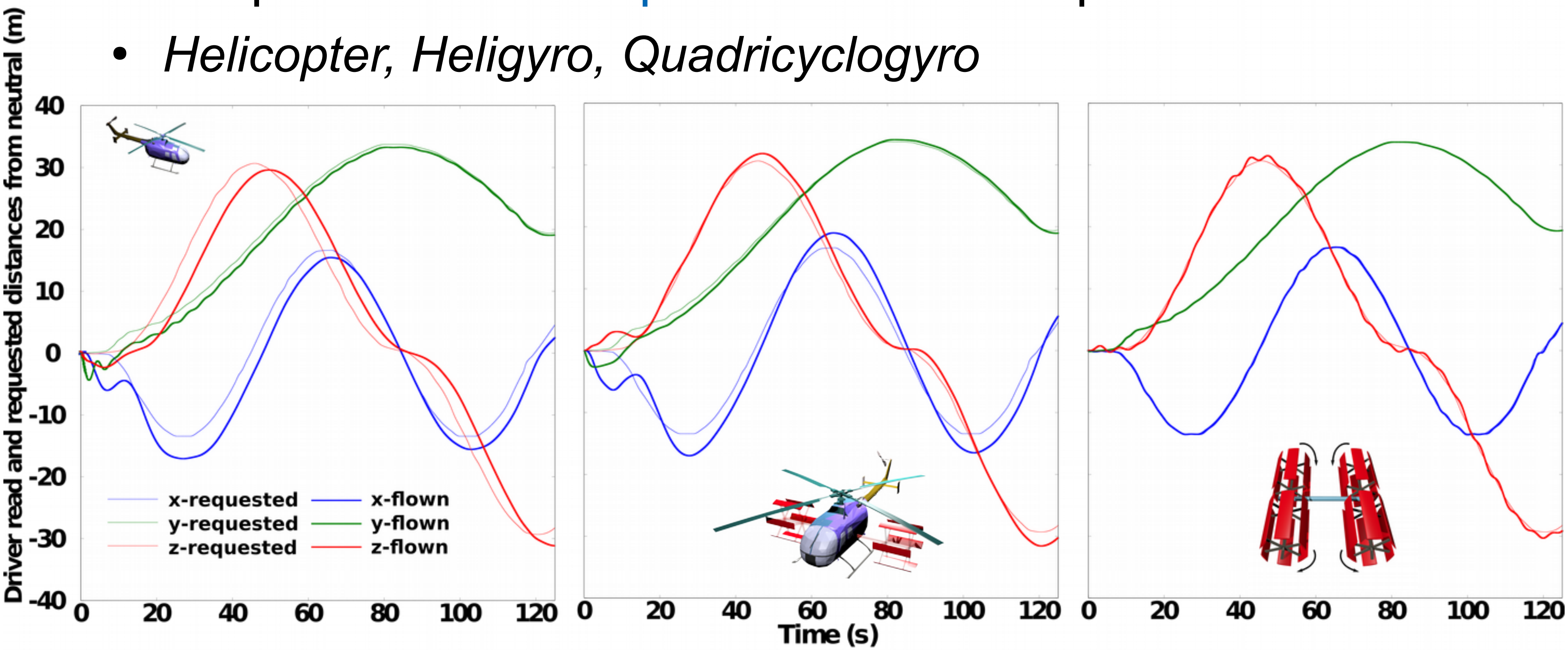
Path-Following Results

- **Hover**
  - comparison btwn requested and flown paths
    - *Helicopter, Heligyro, Quadricyclogyro*



Path-Following Results

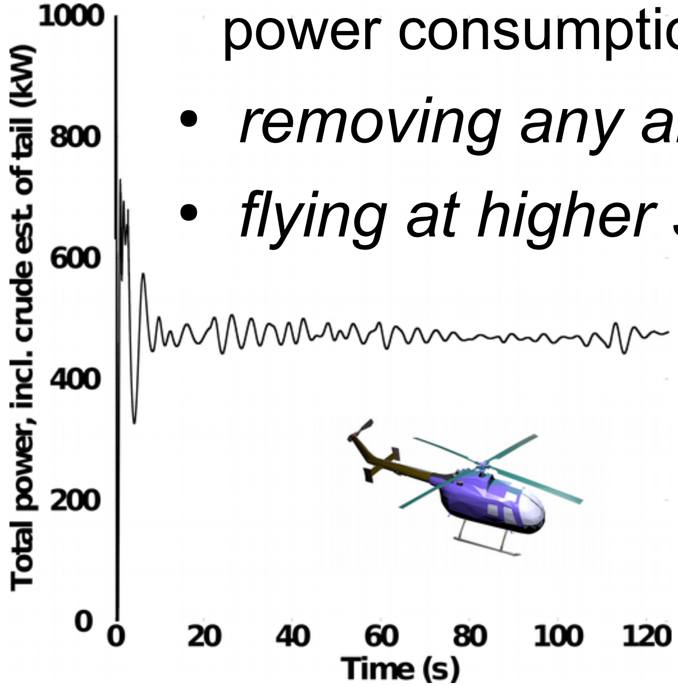
- **“Trickier” path**
  - comparison btwn requested and flown paths
    - *Helicopter, Heligyro, Quadricyclogyro*

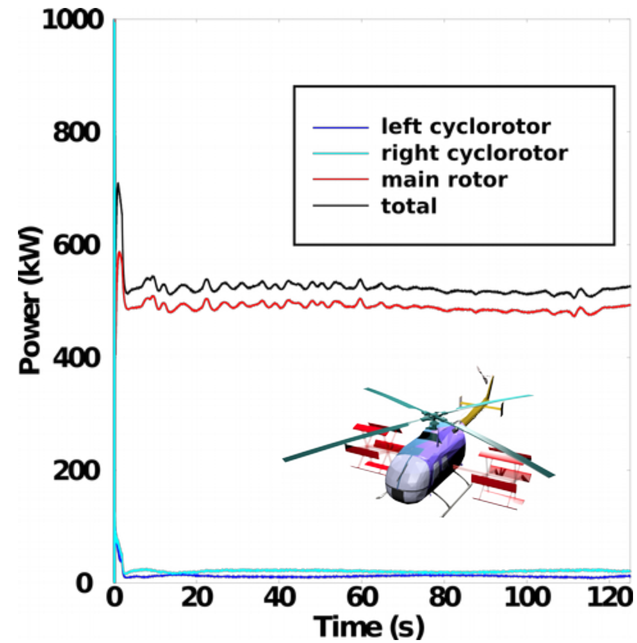


Energy Consumption Results

Heligyro

- **requires similar power than trad. helico.**
  - more testing and adapted controller may lead to reduced power consumption by:
    - *removing any aircraft pitch*
    - *flying at higher speeds*





Conclusion

- **Developed new multibody dynamics models**
  - totally untethered flight
  - tests unconventional configurations
  - embeds unconventional rotors such as cycloidal rotors
- **Constructed a methodology for control**
  - optimized through minimization coupled with power reduction
  - follows challenging paths w/o predictor
- **Heligyro shows good handling properties**
  - slightly more efficient than traditional helicopter

implementation details provided in paper

Thank You for your Attention. Questions?

Video (2 min): https://youtu.be/WSIK4t-Rg1Q

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louis.gagnon@polimi.it & pierangelo.masarati@polimi.it