The ROBUR project: towards an autonomous flapping-wing animat

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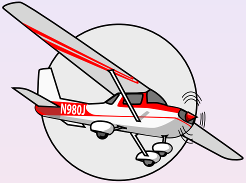
Journées MicroDrones 2004

Designing and building an autonomous flapping-wing aircraft.
autonomous = able to accomplish a given task without any external help.

Introduction: why flapping-wing for a small UAV ?

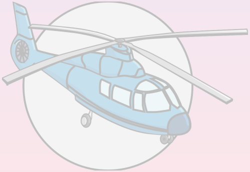
Plane

- + low energy consumption
- - no hovering flight
- - minimum speed



Helicopter

- + hovering flight
- + vertical take-off
- - energy consumption



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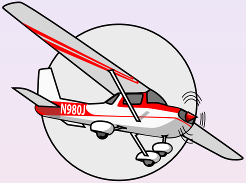

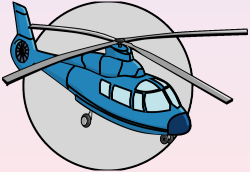

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Flapping-wing aircraft

- + energy consumption
- + near hovering flight
- + almost vertical take-off
- + flying animals...

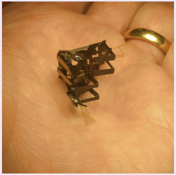
Introduction: Why an autonomous UAV ?

- To avoid remote control
- To save energy
    - adapted low-level control
    - clever trajectories
- To choose the best action to undertake at each time
    - refilling batteries periods
    - exploiting opportunities

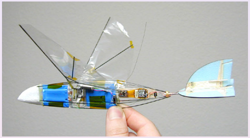
Outline

1. Other flapping-wing projects
2. The ROBUR project
   - Simulator
   - Morphology
   - Motor control
   - Obstacle avoidance
   - Cognitive navigation

Other flapping-wing projects



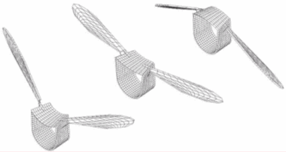
Micromechanical Flying Insect (Berkeley)



Micro-Bat (Caltech)

Entomopter (Georgia Tech)

REMANTA Project (ONERA)



Introduction

Flapping-wing aircrafts: an adaptive systems and artificial intelligence approach.

Target application: artificial gull (wingspan : 130cm).

Why a mini and not a micro UAV ?

- Able to carry enough payload to implement interesting behaviors
- Easier to simulate
- Easier to implement with off-the-shelf components

Project at an early stage: started in 2003

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Project Outline (1)

Required for automatic design algorithms:

- Simulator

Required abilities for complete autonomy:

- adapted morphology
- reactive navigation
  - motor control
  - obstacle avoidance
- cognitive navigation
  - map building
  - localization
  - trajectory planning
  - exploitation of aerological data

Special focus on energy consumption

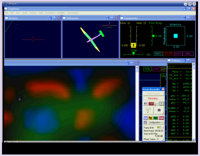
Flapping-wing simulator

Project achievements

Development of a flapping-wing aircraft simulation from Druot's model.

Features:

- 3 panel wings
- 3 DOF per joint
- reconfigurable morphology
- realistic but not exact
- validated on a fixed wing aircraft



Future work

Validation on a flapping wing aircraft

Morphology

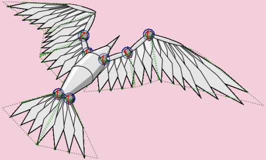
Future work

Required features:

- maximizing maneuvrability
- minimizing energy consumption

Pending issues:

- wing and body shape
- number and position of active joints
- number and position of passive joints



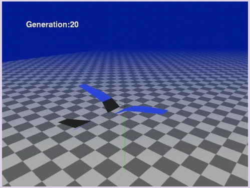
Construction of a real platform

Motor control

Ability to generate and adapt wing beats to the context.

Project achievements

Design of a neural network controller with Evolutionary Algorithms



Future work

- sensory feedback
- wing beats control:
  - on/off for energy saving
  - switch between behaviors (take-off, landing, cruising flight)
- trajectory following

Obstacle avoidance (1)

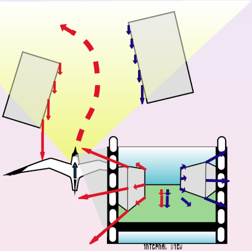
Range sensors:

ultrasonic sensors	⇒	heavy and energy consuming
infrared sensors	⇒	sensitive to external light
lazer sensor	⇒	heavy and dangerous

Classical approaches are not usable !
We must find an alternative: vision

Obstacle avoidance (2)

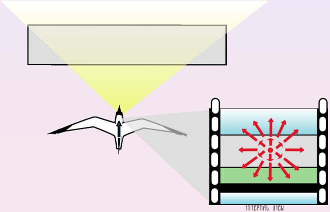
Exploitation of translational optic flow during forward flight.



Optic flow balance to avoid lateral obstacles.
Biological inspiration: bees or common flies.

Obstacle avoidance (3)

Exploitation of translational optic flow during forward flight.



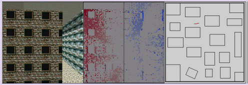
Time to collision computation and u-turn reflex.
Biological inspiration: gannets.

Obstacle avoidance (4)

Project achievements

Experiments on a realistic simulated helicopter.

Rotational optic flow is evaluated and substracted: obstacle avoidance works not only during forward flight



[Muratet, Doncieux, Briere, Meyer 2005 (in press)]

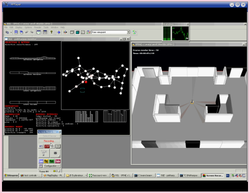
Future work

- application to a flapping-wing aircraft
- validation on a real platform

Cognitive navigation (1): map building, localization and trajectory planing

Future work

Inspiration from work on the Psikharpax project, which aims at building an artificial rat.

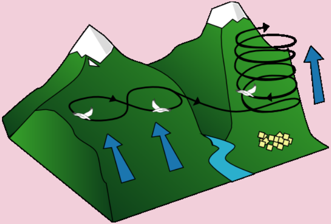


[Filliat et al. 2004]

Cognitive navigation (2): exploitation of aerological data

Future work

Exploitation of aerological conditions



Conclusion

Project achievements

- Simulator
- Low-level motor control
- Obstacle avoidance

Future work

- Trajectory following
- Cognitive navigation
- Real platform construction

Collaborations

- Thierry Druot (Université Paul Sabatier - ENSICA - SupAéro)
- Yves Brière et Pascal Roches (ENSICA)
- Patrick Pirim (BEV)

Publications

- Muratet, L. and Doncieux, S. and Briere, Y. and Meyer J.A. (in press). "A contribution to vision-based autonomous helicopter flight in urban environments". Robotics and Autonomous Systems, 2005.
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- Doncieux, S. and Meyer, J.-A. (2003). "Evolving Neural Networks for the Control of a Lenticular Blimp". In Raidl et al. (Eds). Applications of Evolutionary Computing. pp 626-637. Springer Verlag

Fundings and collaborations are sought...

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