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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**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)

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**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

Doncieux, Mouret, Muratet, Meyer
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Project at an early stage: started in 2003
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

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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

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Future work

Required features:
- maximizing maneuverability
- 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.

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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 planning

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

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Collaborations

- Thierry Druot (Université Paul Sabatier - ENSICA - SupAéro)
- Yves Brière et Pascal Roches (ENSICA)
- Patrick Pirim (BEV)
<table>
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<tr>
<th>Authors</th>
<th>Title</th>
<th>Conference/Journal</th>
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<tr>
<td>Muratet, L. and Doncieux, S. and Briere, Y. and Meyer J.A.</td>
<td>“A contribution to vision-based autonomous helicopter flight in urban environments”</td>
<td>Robotics and Autonomous Systems, 2005</td>
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Fundings and collaborations are sought...

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