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A contribution to vision-based autonomous helicopter flight in urban environments

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Abstract

A navigation strategy that exploits the optic flow and inertial information to continuously avoid collisions with both lateral and frontal obstacles has been used to control a simulated helicopter flying autonomously in a textured urban environment. Experimental results demonstrate that the corresponding controller generates cautious behavior, whereby the helicopter tends to stay in the middle of narrow corridors, while its forward velocity is automatically reduced when the obstacle density increases. When confronted with a frontal obstacle, the controller is also able to generate a tight U-turn that ensures the UAV's survival. The paper provides comparisons with related work, and discusses the applicability of the approach to real platforms.

Keywords: Helicopter; Optic flow; Obstacle-avoidance; Urban environment

Airborne devices are specific platforms whose control raises distinctive difficulties as compared to ground robots. For instance, they can hardly rely upon usual sensors to navigate, especially if the challenge is to let them move in an urban environment – because infrared sensors are sensitive to external light and can only detect nearby obstacles, because sonar sensors are too slow or too heavy for small platforms, and because lasers are too dangerous to be used in the presence of unadvised humans. Not surprisingly, under these conditions, there is currently no obvious solution to the problem of coming up with sensors to equip a small UAV[1] capable of flying in an urban environment without hitting obstacles. This is why, in this paper, we draw inspiration from biology to assess the potential for

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[1] Unmanned aerial vehicle.

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Fig. 1. The Concept 60 SR II.

using vision to tackle this problem. Indeed, because the distance between their two eyes can be very small in many animal species, such individuals cannot rely on stereoscopic vision to assess the distances of surrounding objects [10]. They, therefore, have developed specific neural processes based on motion detection and *optic flow* monitoring to estimate these distances. In this paper, we have implemented such a biomimetic strategy on a simulated helicopter moving in a realistic 3D urban environment to assess its adaptive value under these conditions.

The results described below are based on a realistic physical model of a rotary-wing UAV which is combined with a 3D engine generating images that are fed into an obstacle-avoidance system. This system interacts with a low-level controller responsible for keeping the helicopter as stable as possible. The 3D environment is generated and monitored with crystal space,[2] an open-source software. A real-time correlation-based algorithm is used to compute the optic flow.

The paper successively describes the physical model of the UAV and its low-level controller, the optic flow extraction algorithm, the navigation strategy and its biological basis, and the high-level controller for obstacle-avoidance. The results of several simulations performed in three different urban environments are then presented and discussed. Finally, possible improvements to the system are suggested.

1. The simulated UAV platform

1.1. The physical model

The simulated robot is a rotary-wing UAV inspired from the Concept 60 SR II (Fig. 1), a remote-controlled helicopter produced by Kyosho.[3] It has six degrees of freedom: three coordinates (x, y, z) and three attitude angles, i.e., the yaw (ψ), the pitch (θ) and the roll (ϕ). It weighs 4.5 kg and is 140 cm long, 15 cm wide, and 47 cm high. Its main rotor has a diameter of 150 cm, while that of the tail rotor is 26 cm. It is assumed to be able to carry the visual system described below. To simulate this device, we use Autopilot, a physical simulator that has already been used efficiently for such a purpose.[4]

1.2. The robot's sensors and environment

The navigation strategy implemented in this work calls upon two sensors: a video camera and an inertial and attitude measurement unit (IAMU) supposedly equipped with Kalman-filtered accelerometers, gyrometers and

[2] http://crystal.sourceforge.net.
[3] http://www.alansmodels.com/helis/con60sr2.htm.
[4] http://autopilot.sourceforge.net/gallery.html.