Vision-based Pose Estimation for Autonomous Indoor Navigation of Micro Unmanned Aircraft Systems

Piotr Rudol and Mariusz Wzorek and Gianpaolo Conte and Patrick Doherty
Artificial Intelligence & Integrated Computer Systems Division
Department of Computer and Information Sciences, Linköping University

Introduction

A method for accurate vision-based pose estimation which allows for autonomous navigation of micro-scale UAS’s has been implemented and tested. It is particularly suitable for indoor use which is of special interest for many academic and commercial applications. The system makes use of low cost artificial landmarks placed in the environment and allows for autonomous flight from take-off to landing. All computations are performed on-board a UAS what greatly improves the robustness of the system.

System Overview

In order to navigate, a UAS must be able to localize itself in the environment. Unfortunately, GPS is not available indoors. Similarly, the heading information from a magnetometer is not reliable in indoor environments. A video camera and an algorithm which delivers position and attitude information can be used instead.

Experimental results

The described system has been implemented using the LinkBoard flight control board [2]. Image processing is executed on a 512 MHz processor. Images of 320 x 240 pixels are obtained from a USB camera. Sensor fusion and control is executed on a 60 MHz microcontroller. The LinkBoard, the camera and the wireless modem weigh approximately 50 grams.

The Hummingbird UAS quadrotor has been used as a test platform. It is controlled by means of attitude angles and thrust. The UAS has a diameter of 55 cm with 200 grams of payload. Thanks to LiPo batteries, it has an endurance of up to 20 minutes. Ground control software is used both for development and telemetry data monitoring. Autonomous flight capability is achieved without communication with external entities.

In our solution we use a vision-based pose estimation technique which utilizes the Robust Pose from a Planar Target Algorithm [1]. It uses uniquely coded (4096 available combinations) rectangular markers located in an environment in order to deliver the position and heading information. Markers spread in the environment form a map within which a UAS localizes itself. The markers can be placed in arbitrary poses on the floor, walls, tables etc.

Accuracy and range of the vision-based pose estimation algorithm has been evaluated in a series of Monte-Carlo simulations. In order to achieve position error within centimeter range, the camera can be placed up to 70 cm away from a 10 cm square marker. Thanks to a large number of available markers, they can be of different size. This allows for close- and long-range relative navigation i.e. from take-off to landing.

The vision-based position and heading information is fused with inertial data (from 3-axis accelerometer and 3 rate gyroscopes) by means of a 9 state Kalman filter. It estimates position, lateral and vertical velocities, and attitude. Four PID control loops are used to achieve autonomous flight.