Automatic Take Off, Tracking and Landing of a Miniature UAV on a Moving Carrier Vehicle

Karl Engelbert Wenzel · Andreas Masselli · Andreas Zell

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Abstract We present a system consisting of a miniature unmanned aerial vehicle (UAV) and a small carrier vehicle, in which the UAV is capable of autonomously starting from the moving ground vehicle, tracking it at a constant distance and landing on a platform on the carrier in motion. Our visual tracking approach differs from other methods by using low-cost, lightweight commodity consumer hardware. As main sensor we use a Wii remote infrared (IR) camera, which allows robust tracking of a pattern of IR lights in conditions without direct sunlight. The system does not need to communicate with the ground vehicle and works with an onboard 8-bit microcontroller. Nevertheless the position and orientation relative to the IR pattern is estimated at a frequency of approximately 50 Hz. This enables the UAV to fly fully autonomously, performing flight control, self-stabilisation and visual tracking of the ground vehicle. We present experiments in which our UAV performs autonomous flights with a moving ground carrier describing a circular path and where the carrier is rotating. The system provides small errors and allows for safe, autonomous indoor flights.

Keywords UAV · Tracking · Onboard · Low-cost · Infrared · Microcontroller

1 Introduction

Fully autonomous flights require high precision in aircraft positioning, especially in takeoff and landing phases. When landing needs to be accomplished safely on a
moving target, the problem becomes highly complex. Our system allows a miniature Unmanned Aerial Vehicle (UAV) to takeoff and depart from a carrier vehicle, track it by holding a constant position, approach and land on the vehicle. Our carrier is represented by a Pioneer 2-DX robot with a platform of 43 cm × 82 cm.

Until recently, onboard navigation and target tracking with UAVs have mostly been done by using industrial helicopters of significant size and weight [12, 19]. Thanks to great progress in high capacity batteries and energy efficient brushless motors, UAVs have become smaller and smaller. Equipped with specialized sensors, these miniature flying robots are of high interest for civil and military use, especially for surveillance tasks. Their small size and very light weight also makes them ideal aircrafts for indoor experiments. As most accurate sensors require great processing power, miniature UAVs are often controlled by the help of external sensors and ground stations.

In this paper, we present a low-cost onboard tracking solution. We demonstrate how an inexpensive infrared (IR) consumer electronic camera can be used as the main sensor for stable flight control. The camera is capable of detecting up to four infrared blobs and provides the pixel position of each blob. By leaving the image processing out to the integrated circuit of the camera, the control algorithm can run on an onboard microcontroller at a high frequency without external sensors or a base station. The whole weight of the prototype vision system is below 10 g. This is an important aspect for miniature UAVs, which often are capable of carrying only a few dozen grammes of payload.

The key idea of our approach is to track a T-shaped 3D-pattern of infrared lights, attached to a moving target. The distinct pattern allows for the estimation of the current position, relative to the target. As the camera requires free line of sight to the IR lights, the operation radius is limited to a region from 15 to 250 cm in front of the pattern.

As further enhancement to our previous work of autonomous hovering above and landing on a stationary target with the Wii remote sensor [21, 22], the position of the aircraft is now extracted only from the shape of the pattern. The use of an inertial measurement unit or other sensors for target tracking is no longer required. This makes the system applicable for a huge variety of miniature aircrafts.

As Bouabdallah et al. demonstrated in [2], a classical proportional-integral-derivative (PID) controller is able to control a quadrotor in the presence of minor perturbations. This relatively simple algorithm can be run on the onboard microcontroller at a high frequency of about 50 Hz. The aircraft is landed in a 20 × 20 cm² area, small enough for automatic charging in future projects. Tracking of a fast moving and turning target is possible, as long as the motion change is smooth.

2 Related Work

Most onboard vision-based tracking and navigation have been done on aircrafts of significant size using industrial cameras and high performance processors. Shakernia et al. [16] and [17] introduced a large, single rotor helicopter system (overall length 3.6 m), where the position and velocity to a planar landing pad was estimated by a vision system. A vision-based autonomous landing algorithm was presented by Saripalli et al. [14]. The helicopter of Nordberg et al. [12] is approximately 2 × 1 m².