Chapter 40
Visual Control of an Autonomous Indoor Robotic Blimp

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ABSTRACT

The problem of visual control of an autonomous indoor blimp is investigated in this chapter. Autonomous aerial vehicles have been an attractive platform for a wide range of applications, especially since they don't have the terrain limitations the autonomous ground vehicles face. They have been used for advertisements, terrain mapping, surveillance, and environmental research. Blimps are a special kind of autonomous aerial vehicles; they are wingless and have the ability to hover. This makes them overcome the maneuverability constraints winged aerial vehicles and helicopters suffer from. The authors' blimp platform also provides an exciting platform for the application and testing of control algorithms. This is because blimps are notorious for the uncertainties within their mathematical model and their susceptibility for environmental disturbances such as wind gusts. The authors have successfully applied visual control by using a fuzzy logic controller on the robotic blimp to achieve autonomous waypoint tracking.

INTRODUCTION

A blimp is a special kind of lighter-than-air airship; it does not have a rigid skeleton supporting its balloon. Blimp and airship automation has recently emerged as an attractive field of research due to their properties.

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Unmanned aerial vehicles in general have advantages over unmanned ground vehicles. They are able to reach locations where it is hard for ground vehicles to reach due to hazards or terrain limitations. They also have the advantage of a larger field of view making them able to survey and collect data of a larger area of terrain at a given instance. Unmanned aerial vehicles are also faster and have better maneuverability.

Blimps also have advantages over winged unmanned aerial vehicles and helicopters. Blimps have much safer failure degradation. They are able to hover over one area for a long time, achieve low altitude flights and do not suffer from maneuverability constraints. They also have minimal vibration and do not influence the environment they are in. The properties previously mentioned make them ideal for data collection, exploration, monitoring and research applications. They take off and land vertically. This means that they can be easily deployed with no need for a runway, which makes them attractive as platforms for rescue operations or as communication beacons when communication is cut-off from a certain area. Other attractive properties include long flight durations and low energy consumption as they depend on buoyancy to achieve vertical position. The blimp's relatively slow speed makes it also an attractive platform for computationally expensive algorithms that need many state updates such as simultaneous localization and mapping (SLAM).

Blimps have been studied as a viable platform for rapidly deployable communication beacons (Flahpour et al., 2009), advertisements and atmospheric data collection and analysis. They are also attractive for military operations such as surveillance and rapid equipment deployment. Blimps serve as an option for providing images and information about regions which have suffered natural catastrophes. Map building and localization of targets have also been studied through the work of LAAS/CNRS (Hygounenc, Soueres, & Lacroix, 2004). Astro-explorations are also an application studied by the Jet Propulsion laboratory at NASA (Kampke & Elfes, 2003).

Blimp Used

The Surveyor blimp "YARB" (Yet Another Robotic Blimp), which is a 66" helium blimp, was employed in this project. This robotic blimp is driven by three motors, two propellers and a third vectoring motor. The onboard electronics include a Blackfin processor, color camera and a Matchport wireless LAN interface. A network camera fixed to the ceiling provides the images for the image processing algorithms. The processing is done on a laptop, and the motor commands are sent to the blimp via wireless LAN interface. Testing was performed on a Toshiba satellite pro laptop with i5-520 CPU with 4GB DDR3 SDRAM.

The blimp is 1.68m long and has a maximum diameter of 0.76m giving it a fineness ratio (length/diameter) of 2.2. It has a volume of $0.26m^3$ and a total lift capacity of 0.3kg given that the lighter than air gas used is helium. While hydrogen is a cheaper alternative that provides more lift capacity for the same volume, helium remains the safer choice.

The blimp platform under study has a few drawbacks making its control rather challenging. The most challenging aspects of the control problem are modeling the dynamics of the blimp and accounting for uncertainties. Examples of uncertainties include disturbances in the form of temperature and pressure variations that could vary the size of the blimp's envelope and vary the buoyancy, or disturbances such as wind gusts. Another problem faced in this project is that the blimp's envelope leaks helium varying its buoyancy from one test run to the other. Airship dynamics are also notoriously hard to control due to large moment of inertia (Khoury & Gillett, 2002). Furthermore, the blimp's lack of an internal rigid frame structure makes its envelope susceptible to expansion and contraction due to acceleration, pressure and temperature variations, adding uncertainty to the blimp's dynamic model. Signal latency has also been observed in our platform as well as delay in control signals.

Therefore, the blimp is indeed a hard platform to control; and just like any controller, for successful operation, an input of positional state is essential. The states we are interested in regarding blimp control are: position in three dimensional space, vertical and horizontal velocities, angular position and finally angular velocity. The space