Development of an Intelligent Unmanned Helicopter

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Abstract

This paper describes the current status of and recent results from LIFE and the Sugeno Laboratory project on autonomous control of an unmanned helicopter. A fuzzy-logic-based control system has been developed that enables single inputs (e.g., voice commands) such as *take off* or *turn left*, to replace the aircraft's normal set of rudder, collective, longitudinal cyclic, and lateral cyclic control inputs. This development has enabled us to demonstrate that a novice can use such a system to effectively control an unmanned helicopter without prior knowledge of the vehicle's flight dynamics.

A set of sensors including an inertial flight measurement unit, microwave speed meters, a laser height meter, and a magnetic azimuth sensor have been installed on the aircraft to provide measurements of position, attitude, and higher-order kinematic information. In addition, a movable CCD camera and on-board image processing unit have been added to extract information about the helicopter's visual environment.

1 Introduction

The helicopter has six degrees of freedom in its motions: up/down, fore/aft, right/left, pitching, rolling, and yawing. Therefore it has various flight modes such as forward flight, backward flight, sideward flight, hovering, hovering turn, vertical climb, vertical descent, etc.

A helicopter has four control inputs concerning its flight in addition to throttle control for the rotation of rotors. Coordinating these inputs the helicopters can make various flights.

The problem with the helicopter flight dynamics is that a helicopter is inherently unstable or a poorly damped system. It is easily affected by the natural environment: temperature, wind, etc. Its basic aircraft modes are cross-coupled with no clear division into longitudinal and lateral direction modes. Hence control of a helicopter, though not impossible, is a difficult one indeed, and careless mistakes and excessive workload of a pilot often cause accidents.

0-7803-2461-7/95/$4.00 © 1995 IEEE

2 Hardware System

The hardware system for helicopter experiments consists of a helicopter, a command transmitter, a fuzzy controller, a command receiver, sensors, a wireless camera, and a telemeter.

Helicopter:
The helicopter YAMAHA R50 used in this project is a production model manufactured by Yamaha Motor mainly for agricultural display; 500 models are now in the Japanese market. The dimensions of the YAMAHA R50 are as follows: overall body length — 3.57m, payload — 20kg, engine — 98cc gasoline.

Fuzzy Controller:
Sugeno Laboratory has designed an on-board-fuzzy controller equipped with fuzzy inference chips that can store 1500 fuzzy control rules.

Command Transmitter:
A handheld radio remote controller for YAMAHA R50 is modified so that the operator transmits commands through a keyboard or a voice recognition device.

Sensors:

TMOS 1000: an integrated sensor with a vibratory rate gyros and servo accelerometers to measure three dimensional accelerations, velocities, attitude angles and angular velocities.

Radio Wave Speed Meters: these measure three dimensional velocities.

Laser Height Meter: it measures height by using laser.

Magnetic Azimuth Sensor: it measures the heading direction.

Differential GPS: a Global Positioning System (GPS) measures three dimensional position and velocities using more than four satellites. A differential GPS compensated by another GPS fixed on the ground achieves 30–100 cm accuracy in three dimensional position measurement.

CCD Camera:

Images taken by a CCD camera are wirelessly transmitted to a monitor TV on the ground. These images are used to achieve image guided control using an on-board image processor installed in the helicopter, and also to give commands from the ground by watching a TV screen and referring the telemetered state variables.

3 Software System

The developed intelligent unmanned helicopter is operated basically by fuzzy control. The hierarchical control system as shown in Fig.1 consists of an upper layer and a lower layer.

The lower layer consists of modular fuzzy controllers for four control inputs: (1) longitudinal cyclic, (2) lateral cyclic, (3) collective pitch including throttle, and (4) antitorque pedals.

Each module consists of if-then-type fuzzy control rules such that if (states occur) then (control action is taken). For example, 57 rules are used for control of 'hovering': 18 rules for longitudinal cyclic, 18 rules for lateral cyclic, 12 rules for collective pitch and nine rules for pedal.

The upper layer is divided into four levels where "flight mode management" activates the lower control modules for four control inputs according to a given flight mode.

4 Conclusions

multiple flight modes Hierarchically structured control systems can facilitate the implementation of multiple flight modes because each high-level flight mode controller can take advantage of a common set of lower-level modules that control basic cyclic, collective, and rudder actuator inputs. These capabilities have been demonstrated by commanding the helicopter to execute complex maneuvers, such as figure eights and rectangular flight paths.

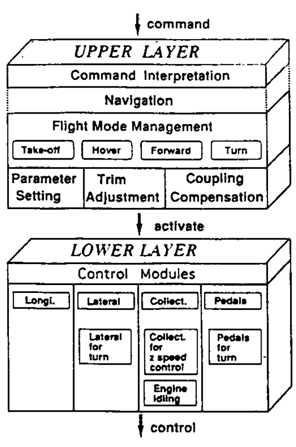

Figure 1: Hierarchical modular control system

transient state control Fuzzy control system can be used to implement transient state control. This capability has been demonstrated by commanding the helicopter to execute transient maneuvers, such as take-offs and landings.

free 3D flight Fuzzy control systems can be used to implement free flight in three dimensional space. Specific control objectives (e.g., precise trajectories) do not have to be specified in the design of a fuzzy control system. Rather, a controller can be designed with knowledge about control strategy that only implicitly includes a control objective. This capability has been demonstrated by commanding the helicopter to execute circular flight without specifying a definite turning radius and also to execute 3D straight flight.

fuzzy commands Fuzzy control systems can be designed to execute fuzzy instructions. Because the overall control system is written in terms of linguistic rules and has a mechanism to understand the meaning of fuzzy concepts, it is able to accept and interpret imprecise commands. We plan to demonstrate this capability by commanding the helicopter to execute such commands as *fly a little slower* or *fly to the right.*

image feedback control Fuzzy control systems can be used to implement image feedback control. Because fuzzy control rules are compatible with both quantitative and qualitative information, visually-derived qualitative information can be used as input to fuzzy control systems. This capability has been demonstrated by commanding the helicopter to visually search for a landing target, position itself over that target, and land in the center of the target. We will describe our new on-board image processing system and report on experiments that use it to track stationary ground targets using pan and tilt camera movements.

References

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