Design and Construction of a Quad Tilt–Rotor UAV using Servo Motor

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ABSTRACT

Unmanned aerial vehicles (UAVs) that have been recently commercialized can largely be divided into fixed-wing aircraft and rotor aircraft by their styles and flight characteristics. Although the fixed-wing aircraft represents higher power efficiency, higher speed, longer flight distance and larger loading weight than the rotor aircraft, they have a disadvantage of requiring a space for take-off and landing. On the other hand, the rotor aircraft can implement vertical take-off and landing (VTOL) and represents various flight modes (hovering, steep bank turns and low-speed flights). But they require both precision take-off control and attitude control. In this study, we used a quad-tilt rotor UAV to combine advantages in both the fixed-wing aircraft and the rotor aircraft. The quad-tilt rotor (QTR) system was designed and constructed by adding a tilt device with a servo motor to a general quad-rotor vehicle.

Keywords: Unmanned aircraft vehicles(UAVs), Quad-tilt rotor(QTR), Tilt-rotor, VTOL, Servo motor,

I. Introduction

Multi–purpose, compact unmanned aerial vehicles (UAVs) have been attracting great attention over the past few decades. These systems can be used in a wide area of civilian and military applications such as surveillance in disasters, traffic monitoring, law enforcement and power line maintenance, marine operations, battle damage assessment, and border detection [1-8].

These application areas lead to more advanced research for increasing the level of autonomy and reducing the size of UAVs. UAVs can be roughly classified into two groups: fixed–wing UAVs and rotary–wing UAVs (e.g., helicopter). Both types have their advantages and disadvantages. Fixed–wing UAVs can fly with a large cruising speed, but an extremely large site is required for takeoff and landing, and it is an unsuitable mission in urban regions. On the other hand, in the case of rotary–wing UAVs, the taking–off and landing sites need not be chosen because they can take off and land vertically. In addition, they can also perform a steady flight operation called hovering; hence, they are advantageous for monitoring fixed points. However, their cruising speed is less than that of a fixed–wing aircraft, and hence, the area on which they can carry out their mission is small [9].

In recent years, hybrid design UAVs that join the vertical flight capabilities of rotary–wing UAVs with the high speed long duration flight capabilities of fixed–wing UAVs have been developed. Despite their increased mechanical complexity and more difficult control, they are very desirable for their ability to act like both fixed–wing and rotary–wing UAVs, since this ability is very useful in various missions. Among these hybrid designs, tilt–rotor UAVs constitute an attractive research area due to their stability, energy efficiency and controllability [10-12]. The tilt–rotor UAVs can realize vertical take–off and landing (VTOL), hovering, and high cruising speed flight by changing the angle of the rotor side by a tilt mechanism.

In this paper, a smart electric powered quad tilt–rotor (QTR) UAV is presented. It has four rotors which are mounted on the four wings. The wings, together with the rotors, are tilted between vertical and horizontal configurations to accomplish vertical and horizontal flights. The tilt mechanism
can be actuated by servo motors. The flight mode of QTR-UAV can be changed by tilting the rotors on the wings. The first flight mode is the helicopter mode, and in this mode, the QTR-UAV can takeoff and landing vertically and it can hover on a fixed point. The second flight mode is the airplane mode, in this mode, the QTR-UAV can fly like an airplane, and it is possible to move at high speeds. The objective of this study is to develop a smart quad tilt-rotor system that shows a simple structure and can implement VTOL by combining advantages in both fixed-wing UAV and rotary-wing UAV.

II. Operation of Quad Tilt–Rotor UAV

A QTR aircraft is a new concept complex UAV combining advantages of conventional take-off and landing (CTOL) vehicle and VTOL vehicle, which includes all characteristics of VTOL aircraft and CTOL aircraft. When the rotor angle is 0°, it has VTOL aircraft characteristics while it makes a flight with CTOL aircraft characteristics when over 0°. Like this, according to the change of the rotor angle, the characteristics of UAV’s motion is changed. The operating modes of the QTR-UAV can be divided into VTOL mode, transition mode and CTOL mode as shown in Fig. 1 [13-14].

1. Operation in VTOL mode

In VTOL mode, the tilt angle of wing’s rotor is 0° and the axes of the propellers are tilted in the vertical direction. Thus it can make VTOL and hovering flight. It also has VTOL aircraft characteristics. Because the lifting force, which lifts the vehicle, is generated only by the propeller thrust, it is an operating mode with the lowest fuel efficiency. Therefore, it is favorable to have a short operating time in VTOL mode by changing to transition mode in a short time after vertical take-off.

2. Operation in transition mode

Transition mode is the middle process between VTOL mode and CTOL mode, in which the wing tilts in the process of the flight to change from VTOL to CTOL. The propeller thrust that serves as the main lift force works in the forward direction and the lift force on the wing gradually increases. An appropriate tilt angle has been determined depending on its velocity, and an excessive or insufficient tilt angle would cause a structural problem and an unstable flight characteristic.

3. Operation in CTOL mode

CTOL mode is a cruising flight state in which tilting is completed with the wing’s tilt angle of 90° through transition mode. The vehicle has CTOL aircraft characteristics and the thrust of the propeller is in the forward direction, and the lift force acting on the vehicle is generated by the wing. Therefore, this is an operating mode with the highest efficiency. In this mode, the flight speed is high.

III. Construction of QTR–UAV

1. Configuration of control system

The vehicle was operated by control signal sent from R/C transmitter. Fig 2 shows block diagram of flight control system of the QTR-UAV. In order to obtain data from sensors and to stabilize rotors, a controller is required. As a controller in the vehicle, ATmega2560 and APM2.0 board were used.

APM2.0 board is equipped with a tri-axial gyro sensor, a tri-axial accelerometer sensor, a tri-axial geomagnetic sensor, a barometric pressure sensor and GPS. The controller receives attitude data from a sensor through I2C (Inter-Integrated Circuit) communication. After data processing, it generates a PWM signal and controls rotation speed of the rotor to manage the vehicle’s motion. As a rotor for propulsion and high power efficiency of the vehicle, a brushless DC motor (FlyCam925), which maintenance is almost not required, was used. For control of constant speed velocity of rotor, SBEC 20A of FlyCam was adopted as an electronic speed control (ESC). The sensor module included a