Microcontroller Based Rudder Control System for Autonomous Flight Vehicle

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***Abstract* — This paper addresses the control system to control required yaw position of autonomous flight vehicle. This system operates in two operational modes: manual control mode and automatic control mode. In the manual control mode, the signals from RC receiver are read, manipulated and also sent to the servo motor. Therefore should the rest of the system fail, it is possible to maintain manual control. In the automatic control mode, the computed value is applied to the servo motor. In case of the manual-to-auto mode change, the controller value is set so that the action value is equal to current manual action value, to ensure no bumpy control transition. In order to ensure stable control, the deflection angle is limited in the allowable range. The control algorithm has been implemented into the microcontroller that receives position commands, creates PWM signals for servomotor, and switches between pilot and auto control. For this control technology, the assembly programming language has been used.**

***Keywords* — rudder control, manual control, automatic control, microcontroller, assembly programming language.**

I. Introduction

Various kinds of autonomous flight vehicle have been developed for various purposes. The autonomous flight vehicles offer advantages over conventional manned vehicles in many applications because they can be used in situations otherwise too dangerous for manned vehicles and without being weighed down by a pilot.

They have drawn considerable interest because of their small size, portability, low cost and expendable platforms for surveillance and data collection in situation where large vehicles are not practical. There are also a number of civilian and commercial applications, mostly for research purposes. These includes (but not limited to) environmental monitoring, natural resource assessment, wildlife monitoring, bushfire monitoring, search and rescue, telecommunication, precision agriculture, power line inspection and pipeline petrol. [1]

They can be controlled by the pilot manually using the R/C transmitter or by predefined flight path automatically. The flight control system autonomously enables stable flight according to the prearranged flight track with specified altitude and airspeed. Not only do the automatic flight vehicles provide excellent low-cost test beds for navigation system experiments, but their design and control facilitate the exploration of many exciting new research areas in control theory, ranging from low-level flight control algorithm design and mode switching experiments to high-level multiple aircraft coordinated mission planning. [2]

First, the orientation of flight vehicle is placed to get the required yawing movement manually until the craft is in steady level flight. At the automatic mode, the control system senses the current position of craft and adjusts the yawing movement to be stable in the required position. For roll and pitch control, flight stabilization system (co-pilot) has been used.

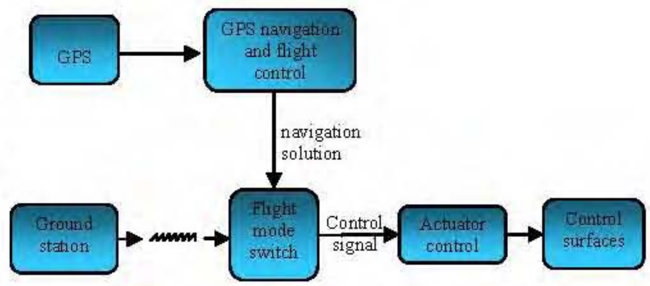

Fig. 1 Simple avionics system of autonomous flight vehicle

II. System Architecture

The airplane used for this research as the test bed is MAEU01 shown in Fig. 2. In the standard configuration, three servos are used in MAEU01 for guidance and control. These allow the pilot to command elevator, aileron, and rudder. For aileron control, a single servo differentially actuates two control surfaces, one on each side of the wing.

Fig. 2 MAEU01 autonomous flight vehicle model

The servo motors are geared dc motors with positional control feedback and are used for position control. The servo used for actuation is the standard Futaba S-9102. This kind of servo motor was chosen according to its advantages: high torque at all speeds, able to accelerate and decelerate to reach a position or rate of speed quickly, able to reverse directions quickly and capable of holding a static position. [3]

Fig. 3 Standard Futaba S-9102

TABLE I
FUTABA S-9102 STANDARD SERVO

Specifications	
dimensions	1.6″× 9″× 1.0″
weight	1.6 oz
torque	50 oz-in
deflection speed	0.17 sec/60˚
operating voltage	4.8 V

The specification of Futaba S-9102 is described in Table 1. The standard R/C control linkages and horns are used to connect the servo control actuator with the control surface. There are three leads to a servo. Two leads are for power, + 4 to 6 volts and ground. The third lead feeds a position control signal to the motor, and the control signal is a variable-width pulse. [4]

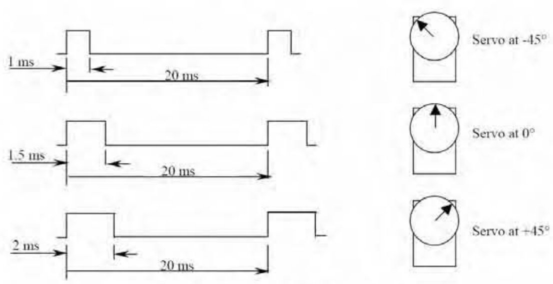

Fig. 4 Servo motor pulse signal

The R/C servo operates upon the command of a square-wave. The length of the wave tells the servo which position to assume. A standard R/C transmitter with its receiver provides this square-wave input to the individual servos. Each servo is on a separate channel (frequency), and can therefore be controlled independently. The actuation range of the servo is +/- 45 degrees. The square wave length varies between duration of 1 millisecond to 2 milliseconds. At duration of 1 millisecond, the servo will assume a position at one extreme end of its travel that is -45 degrees. At the other extreme of 2 milliseconds, the servo will travel to the opposite extreme of travel that is +45 degrees. Therefore, a square-wave input of 1.5 ms will command the servo to position its output arm to the mid-position. Since a square wave is outputted 50 times per second, these square wave pulses are delivered to the servos approximately every 20 ms. The horn of servo will rotate range of 0 to 90 degree angles as shown in Fig. 4. [5, 6]

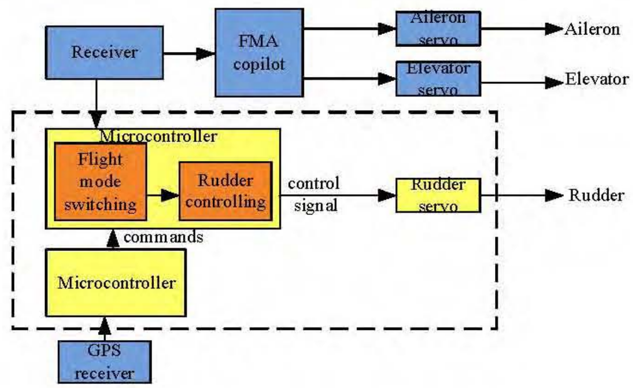

Fig. 5 Data flow and components of control system

This paper focuses only on the control of rudder actuation, as shown in dotted block of Fig.5, using the received commands from GPS navigation. For stable control, the craft should be controlled manually until it reaches the stable condition and then automatic flight mode has been chosen. The flight stabilizer is used and it looks at the horizon with infrared heat. The earth is warmer than the sky [7]. Copilot sees this temperature difference, and sends corrective signals to the Roll and Pitch servos, in consequences, to keep the aircraft level.

III. CONTROL SYSTEM

For this research, both hardware and software needed to control the servo has been developed. The PIC microcontroller is used to detect and analyze the PWM signal for flight operation mode; the PWM signal is fed into an internal timer module of the microcontroller where the rising and falling edges of the PWM signal is examined to determine the duration of the pulse [8]. The system enables two distinct flight modes: manual and automatic. The PWM duration less than neutral position of 1.5 milliseconds, it is assigned as manual mode and that greater than neutral is assigned as automatic mode [9].

Fig. 6 Transmitter and receiver

In remote operation mode, the pilot standing on the ground observing the airplane commands the input to control actuator using a hand-held radio controlled R/C transmitter shown in Fig.6. The transmitted signals are received by the airborne receiver which in turn sends signals to the microcontroller. The signal from the R/C receiver, shown in Fig.6, to the microcontroller, shown in Fig.7, is in the form of pulse width modulation (PMW) by varying the duty cycle, changing the high pulse from 1ms to 2ms. The MCU reads and interprets pilot commands, then controls servo appropriately because the servo is not controlled directly by the pilot. Open-loop control is used to actuate the servo. Since no sensor feedback is used, the motion is based strictly on pilot input.

When the autonomous mode is activated, the flight mode redirects the computed control outputs from navigation loop to the microcontroller. The microcontroller performs these functions: setting the action value to be equal to current manual action value, reading the command signal, checking the current yaw position, computing the control algorithm, and commanding the servo position.

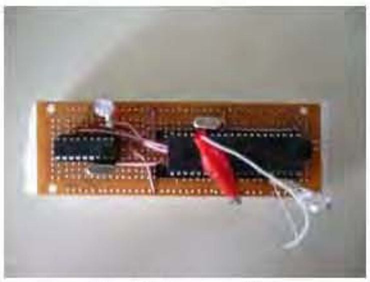

Fig. 7 Microcontroller

When the auto mode command is received by an MCU, the current manual PWM duration is grasped and set as the action value to get no bumpy control transition. The rudder degree and turning direction is received using the serial data reception. The microcontroller checks the received degree whether it is in the allowable rudder deflection limit of +/- 10 degrees. Since deflecting the rudder fully in one direction will cause the aircraft to roll in addition to yawing, the rudder deflection has to be limited. If it is deflected long enough, the craft will begin a downward spiral and lose stabilization. So a small amount of deflection in each direction is needed to turn the aircraft.

Fig. 8 Rudder control surface actuator

The microcontroller performs the command of degree and turning direction in the form of numerical positions and generates the pulse width modulation signals needed to communicate with the servo to give the appropriate movement angle for rudder within allowance. Fig. 8 shows the rudder control surface mounted with servo.

IV. SOFTWARE IMPLEMENTATION

The source code is implemented in assembly language. Fig. 9 is a flowchart of the body of the program used to control the yaw position of the air craft. The first part of the program initiates the input/output pins and registers needed throughout the program. The interrupt service routines such as timer 0 interrupt, USART receive interrupt and CCP hardware interrupt are also defined. The capture/compare/pulse width modulation (CCP) hardware was used to determine the length of digital pulses from the R/C receiver.

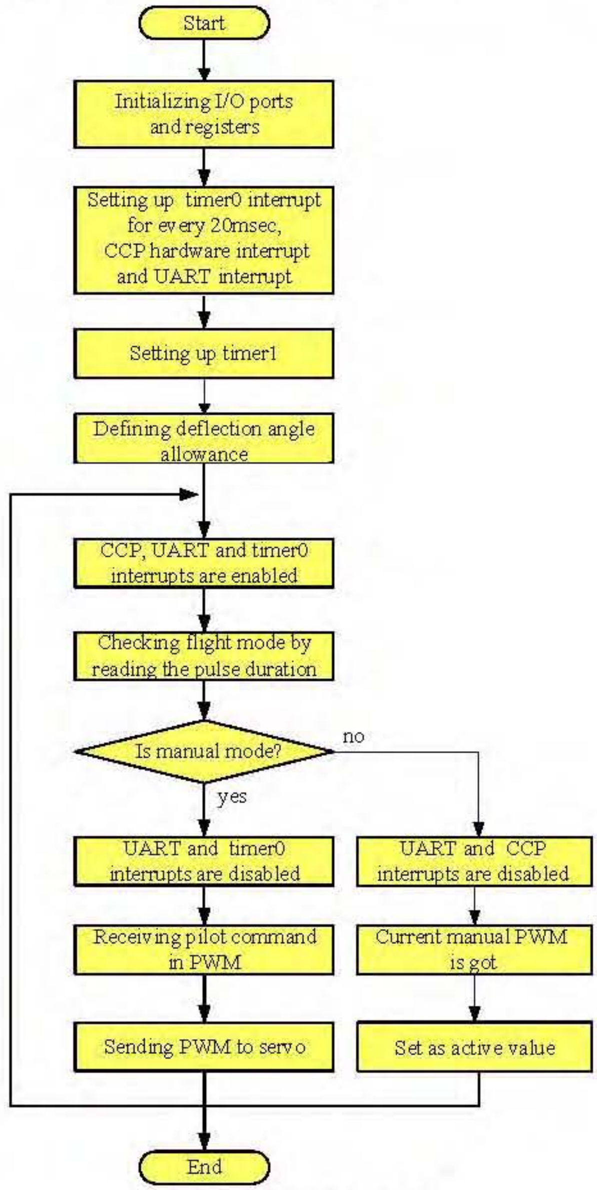

Fig. 9 Flow chart of main program