www.ijrream,in Impact Factor: 2.9463
INTERNATIONAL JOURNAL OF RESEARCH REVIEW IN ENGINEERING AND MANAGEMENT (IJRREM)
Tamilnadu-636121, India
Indexed by
Scribd impact Factor: 4.7317, Academia Impact Factor: 1.1610
ISSN NO (online) : Application No : 17320 RNI –Application No 2017103794

"High Speed Hardware Efficient PID Controller for Micro air Vehicle on FPGA"

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Abstract

This project This project proposes to design an efficient PID controller for Micro Air Vehicle (MAV) using field Programmable Gate Array (FPGA) technology. FPGA based realization offers high speed, complex functionality consume less power and provides parallel processing. In this project implementation of PID control module on programmable logic design software Xilinx ISE 13.1 and MATLAB will be carried out and will be validated on Spartan 6 FPGA. Distributive arithmetic algorithm for multiplier-less architecture will be designed and implemented to meet design requirements of MAV. FPGA has advantages such as flexible design, high reliability and high speed. In this project, modular design of embedded feedback controllers using the Field Programmable Gate Array (FPGA) technology is studied. To this end, a novel Distributed Arithmetic (DA)-based Proportional Integral Derivative (PID) controller algorithm is proposed and integrated into a digital feedback control system.

The DA-based PID controller demonstrates 80% savings in hardware utilization and 40% savings in power consumption compared to the multiplier-based scheme. It also offers good closed-loop performance while using less resources, resulting in cost reduction, high speed, and low power consumption, which is desirable in embedded control applications. The complete digital control system is built using commercial FPGAs to demonstrate the efficiency. The design uses a modular approach so that some modules can be reused in other applications. These reusable modules can be ported into Matlab/Simulink as Simulink blocks for hardware/software co-simulation, or can be integrated into a larger design in the Matlab/Simulink environment to allow for rapid prototyping applications.

I- INTRODUCTION

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Unmanned aircraft (UA) have been used for military purposes such as reconnaissance, weapons delivery, battlefield communications, and hazardous environment. Examples of UAs are reconnaissance and weapons delivery, disaster management, toxic chemical detection and border security. Micro air vehicles (MAV) are becoming popular on the battlefield, as they are easily transported and deployed by soldiers in the field. MAVs have become cheaper, smaller and easy to transport, non-military applications are gaining interest such as pizza delivery, postal services and home security. As non-military uses become more popular, creating user-friendly MAVs is the need for commercial viability. MAVs are finding their way into law enforcement, crop surveillance, fire fighting, communication relays, search and rescue, etc. Auto piloting of Mavs is required as they need to be managed without human intervention.

Most commercial autopilots used in MVAs must be had-tuned when installed in an aircraft. This involves an experienced remote control (RC) pilot flying the MAV to tune proportional-integral-derivative control (PID) gains and trim the airplane. Such a process can be expensive and time intensive. Due to manufacturing processes, temperature sensitivities, crashes, and changing atmospheric conditions, the tuned values vary from aircraft to aircraft and sometimes on each airplane throughout the day. For many applications, tuning the autopilot can range from annoying to unacceptable. Thus, an autopilot should be self-tuning and fault tolerant.

Adaptive control schemes show promise for fulfilling these requirements. PID values are different for each MAV, even if they have the same physical geometry. The MAV is a Quad rotor which has four rotors and autopilot on board. The Quad rotor is controlled by the pilot Remote Control that communicates with transmitter-receiver pair.

The autopilot on-board communicates with the pilot, who in turn manually controls the movement of the MAV. For autonomous navigation, a predefined path is loaded into the autopilot and the autopilot guides the MAV in the predefined path by considering the inputs from sensors, GPS and environmental parameters.

Mathematical models of Unmanned Aircraft Vehicle (UAV):

The mathematical model for MAV has been arrived at with reasonable assumptions for mass and moment of inertia are constant. Motion Nonlinear Equations of UAV are as follows [1]:

$$\dot{U} = -9.8\sin\theta - QW + RV - 0.0125U - 16.36\alpha + 16.6\delta_E + 4.5$$

$$\dot{V} = 9.8\sin\phi\cos\theta + PW - RU - 263.7\beta - 0.0053P + 1.64R - 0.0032$$
$$\delta_A - 58.2\delta_R$$

$$\dot{W} = 9.8\sin\phi\cos\theta + QU - PV - 0.069U - 259\alpha - 1.3Q + 57.5\delta_E + 21$$

$$\dot{P} = -1.51QR + 0.04PQ + 76.7\beta - 1.9P - 0.68R + 149\delta_A + 105\delta_R$$

$$\dot{Q} = 1.03PR - 0.017(P^2 - R^2) - 988\alpha - 8.9Q + 1362\delta_E - 0.284$$

$$\dot{R} = -0.038QR - 0.85PQ + 306\beta - 0.044P - 2.82R + 2.27\delta_A + 434\delta_R$$

$$\dot{\alpha} = \frac{\dot{W}\cos\alpha - \dot{U}\sin\alpha}{V_t\cos\beta}$$

$$\dot{\beta} = \frac{1}{V_t}[-\dot{U}\cos\alpha\sin\beta + \dot{V}\cos\beta - \dot{W}\sin\alpha\sin\beta]$$

$$\dot{\phi} = P + Q\sin\phi\tan\theta + R\cos\phi\tan\theta$$

$$\dot{\theta} = Q\cos\phi - R\sin\phi$$

$$\dot{\psi} = (Q\sin\phi + R\cos\phi)\sec\theta$$

$$\dot{h} = V_t\sin\gamma$$

$$V_t = \sqrt{U^2 + V^2 + W^2}$$

$$\gamma = \theta - \alpha$$

$$\delta_E = \delta_{E\min} + \delta_e$$

This parameter such defined δE is Elevator angle, δEmin is Elevator angle in trim condition, δe is Elevator angle Compared to amount of trim, δR is Rudder angel, δA is Aileron angle, h is height, Φ is Roll angle, is Pitch angle, Ψ is Side angle, P is Rate of Roll angle, Q is Rate of pitch angle, R is Rate of yaw angle, U Longitudinal velocity, W is Vertical velocity, V is Lateral velocity, Vt is the total Rate, α is Attack angle and β is lateral movement angle. Some variables of UAV are defined in the Figure 1. The purpose is design the Autopilot for height, which is capable to control the height of Aircraft by using the elevator height. Equation 1, shows the nonlinear behaviour UAV. By linearization the nonlinear Equations around trim flight Cruise condition, nominal linear model for height be made in the Transfer Function or Equation 2.

$$\frac{h(s)}{\delta_e(s)}=\frac{-57.3(s-24.6)(s+21)(s+0.008)}{s(s^2+0.011s+0.022)(s^2+2.12s+98.4)}$$

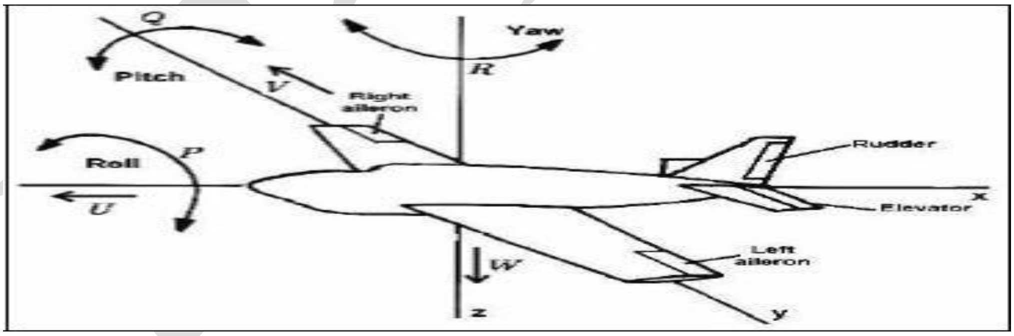

Figure 1 Flight Parameters of Unmanned Aircraft along the three coordinate

To investigate the strength parameter of autopilot, we used the linear non-nominal model. In linear non-nominal model we assume an important stability derivative such as C Du, C ma, C mq and CLu , shows as Table 1. With applying the change, the nominal non-linear Transfer Function model obtained as follows; by Equation 3.

$$\frac{h(s)}{\delta_e(s)} = \frac{-57.3(s-25.5)(s+21.6)(s+0.0017)}{s(s^2+0.0055s+0.021)(s^2+1.82s+64)}$$

------ (3)

Design of Classic Autopilot

In common, designed Autopilot for Height based on special structures that have three-ring. In this structure, the Rate of pitch angle, Pitch Angle and Height measured, such that Autopilot (Controller) for Pitch Angle is the inner loop for Height Autopilot, and the Rate controller of Pitch Angle is inner loop for pitch Autopilot. This makes the structure to be Robust against the complex parametric uncertainty. So should be designed 3 controllers and measured 3 variables. In this project, the Pisxxtch Angle and rate of Pitch – Angle becomes removed and we used a single-loop structure. In this simple structure, height measured just by the altimeter. In this section, the Angle and Height classic Autopilot, will designed for the nominal linear model. By using a nominal linear model and root locus method, the Compensator Transfer Function will design, it’s Equation 4.

$$G_{C_b} = \frac{0.012(s+0.05)(s^2+2.12s+98.4))}{(s+20)(s^2+6s+15.25)}$$

---- (2)

-----------(4

It is assumed that the nominal linear model is a mathematical model, so that it developed based on Autopilot. The relationship between height output variable and input Elevator variable has unstable zero. Moreover flight characteristics in short period and Phugoid mode are undesirable. In Compensator designing, a lot of efforts reduce the effects of an unstable zero. Phugoid and short period modes improved. In [3] and [12] also used this method to design compensator, by given ζ=0.6, ωn = 2.31 in Figure 2.

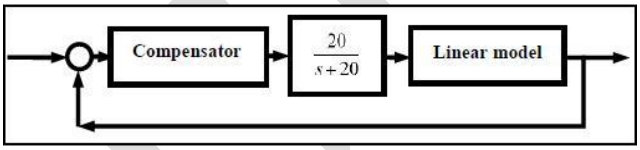

Figure 2 Control modes for design the height compensation

To evaluate the Autopilot, it is necessary to set the height and side angle to nominal linear model. The height is set to 10 meters, and the side angle is between 0 to10.

Design of PID Controller

Industrial PID controllers are usually available as a packaged, and it's performing well with the industrial process problems. The PID controller requires optimal tuning. Figure 3 shows the diagram of a simple closed-loop control system. In this structure, the controller (Gc(s)) has to provide closed-loop stability, smooth reference tracking, shape of the dynamic and the static qualities of the disturbance response, reduction of the effect of supply disturbance and attenuation of the measurement noise effect.

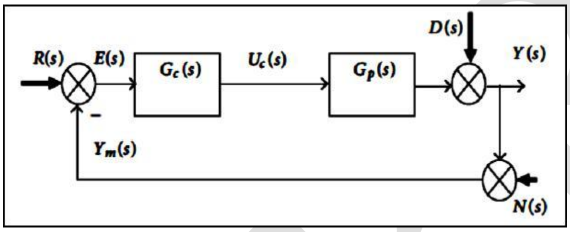

Figure 3 Closed-loop control system

In this study reference tracking, load disturbance rejection, and measurement noise attenuation are considered. Closed-loop response of the system with set point R(s), load disturbance D(s), and noise N(s) can be expressed as Equations 5.

$$Y(s)=\left[\frac{Gp(s)Gc(s)}{1+Gp(s)Gc(s)}\right]R(s)+\left[\frac{1}{1+Gp(s)Gc(s)}\right]D(s)-\left[\frac{Gp(s)Gc(s)}{1+Gp(s)Gc(s)}\right]N(s)$$

$$Y(s)=[T(s)^{*}[R(s)-N(s)]+(S(s)^{*}D(s)] \qquad (5)$$

Where the complementary sensitivity function and sensitivity function of the above loop are represented in Equation 6, respectively.

$$T(s)=\frac{Y(s)}{R(s)}=\left[\frac{Gp(s)Gc(s)}{1+Gp(s)Gc(s)}\right]$$

$$S(s)=\left[\frac{1}{1+Gp(s)Gc(s)}\right]$$

----------- (6)

The final steady state response of the system for the set point tracking and the load disturbance rejection is given in Equation 7, respectively:

$$y_R(\infty)=\lim sY_R(s)=\lim_{t\longrightarrow\infty} sx\left[\frac{Gp(s)Gc(s)}{1+Gp(s)Gc(s)}\right]\left(\frac{A}{s}\right)=A$$

$$y_D(\infty)=\lim_{t\longrightarrow\infty} sx\left[\frac{1}{1+Gp(s)Gc(s)}\right]\left(\frac{L}{s}\right)=0$$

A

------- (7)

Where A is amplitude of the reference signal and L is disturbance amplitude. To achieve a satisfactory yR(∞) and yD(∞), it is necessary to have an optimally tuned PID parameters. From the literature it is observed that to get a guaranteed robust performance, the integral Controller gain “Ki” should have an Optimized value. In this study, a no interacting form of PID (GPID) Controller Structure is considered. For real control applications, the

Feedback Signal is the sum of the measured output and Measurement noise Component. A low pass filter is used with the derivative term to reduce the effect of measurement noise

CONCLUSION

Tuning the controller requires knowledge of the relationship between the input and output variables of the system to be controlled. Since the UAV is a complex nonlinear system, this relationship between the input signal and the output signal is not so simple. However around some operating point, the relationship between the signals can be described by a linear model. The results were obtained through simulations in Matlab and experiments on the model. The simulations possessed a key role, contributing to the tuning of the PID controller in a controlled environment. Both the simulations and the experiments, used the same reference signal or set-point signal, which is equivalent to performing a shift of the UAV in X and Y directions, returning to the initial position afterwards. Although PID controllers work well on Miniature Air Vehicles (MAVs), they require tuning for each MAV. Also, they quickly lose performance in the presence of actuator failures or changes in the MAV dynamics. Adaptive control algorithms that self tune to each MAV and compensate for changes in the MAV during flight need to be explored.

REFERENCES

1.Joao Lima, Ricardo Menotti, Joao M. P. Cardoso, and Eduardo Marques, “A methodology to design FPGA based PID controllers,” 2006 IEEE International Conference on Systems, Man, and Cybernetics October 8- 11, 2006, Taipei, Taiwan.

2.Sirin AKKAYA, Onur Akbati, and Haluk Görgün,“Multiple closed loop system ntrol with digital PID controller using FPGA," 2014 IEEE International Conference on Control, Decision and Information Technologies.

3.Hsiao YT, Chuang CL, Jiang JA. A hybrid of e-constraint and particle swarm optimization for designing of PID controllers. IEEE Int Conf Syst 2005;9(October).

4.Genovese M, Napoli E. ASIC and FPGA implementation of the gaussian mixture model algorithm for real-time segmentation of high definition video. IEEE Trans Very Large Scale Integr (VLSI) Syst 2014;22(3):537–47.

5.Langari G, Tomizulta A. Self organizing fuzzy linguistic control with application to arc welding. In: IEEE international conference of workshop on intelligent robots and systems, vol. 2; 1990. p. 1007–14.

6.Canudas C, Astrom KJ, Braun K. Adaptive friction compensation in DC motor drives. IEEE J Robot Automat 1987;RA-3(6):681–5.

7.Kung YSh, Tsai MH. FPGA realization of an adaptive fuzzy controller for PMLSM drive. IEEE Trans Ind Electron 2009;56(8)