International Journal of Engineering & Technology, 7 (2.33) (2018) 461-465

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Stabilization of UAV using delta sigma modulator

V. Vinoth Kumar [1] *, E. Balasubramanian [2], S. Mano [3]

[1] *Assistant Professor, Department of Electronics and Instrumentation Engineering, School of Electrical and Communication, Vel Tech Rangara-jan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai-62, TamilNadu, India*
[2] *Associate Professor Mechanical Engineering, School of Mechanical and construction Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai-62, TamilNadu, India*
[3] *Assistant Professor, Department of Mechanical Engineering, Sastra Deemed University, Tanjore, TamilNadu, India*
**Corresponding author E-mail: vinothkumarv@veltech.edu.in*

Abstract

The design development and control of Unmanned Aerial Vehicles (UAV's) have stimulated great significance in the automatic control research for the past 2 decade. In specific, Quad rotor systems are promising platform in the area of UAV research, due to its simple in construction, maintenance, ability to hover, and their vertical takeoff and landing (VTOL) capability. The dynamics and control of quad rotor are highly non-linear and under actuated so it is consider as a test-rig to verify any new proposed nonlinear control algorithm. Different control algorithms were proposed and implemented to stabilize the UAV attitude, and altitude. Adaptive control and navigation algorithms also implemented in UAV platform to ensure the maneuvering against the internal and external disturbances. The proposed research paper explains the implementation of developed digital control algorithm Delta-sigma modulator (DSM) based controller for UAV to enhance the robustness.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

The unmanned aerial vehicles are used in multiple vehicle teams, mobile sensor networks, gathering the details for the various real time applications like traffic monitoring, military applications, real time data acquisition and much more the quad rotor UAV takes up the important role. Compared with existing helicopters, quad rotors are having simple in construction avoiding the complex mechanical linkage structures which lessens the weight of system.

In addition, the individual four rotors are smaller in size compared with the main rotor on a helicopter which can also reduce the weight. The quad rotors can reach at different altitude levels in the closely clustered or dense environments. They have an Autopilot so there is no need of human pilot to control the aerial vehicle. The control of an quad rotor may be done by using radio frequency control from ground station or automatic control these control strategies being studied by many researchers.

In [1], PID control is used in most of the places to control the robotics and even for industrial automation. The same scenario in UAV platform too. In [2], PID controller used in quad rotor for both its attitude and altitude control. It observed that it have better performance in pitch angle tracking. In [3], Position and orientation of a quad rotor was regulated by PID controller. Obtained performance shows good attitude stabilization. After PID controller LQR controller are also implemented in Quad rotor control. In [4], Runcharoon and Srichatrapimuk formulated a SMC based on Lyapunov stability theory. It's tracking feature was effective with injected noise which showed good robustness. In [5], Fang and Gao formulated integrator back stepping control by adding integrator in algorithm which results increase in robustness of the general back stepping algorithm. In [6], Diao et al implemented a continuous time varying adaptive controller where known uncertainties in mass, moment of inertia and aerodynamic damping coefficient exist. In [7], Palunko et.al. Implemented Adaptive control scheme for quad rotor using feedback linearization with dynamic changes in centre of gravity. In [8], an adaptive control technique based on rectilinear distance (L1) norm was used with a trade-off between control performance and robustness which was able to compensate for constant and moderate wind gusts. In [9], Bai et.al.implemented a powerful controller for pitch, roll and yaw control system and these mechanism is based on compensation technique. In [10], Tony and Mackunisy deals by using powerful control algorithm to reduce the various environmental disturbances to the system. In [11], optimal control algorithm implemented for tracking of both attitude and heading which gives effective performance. In [12], Falkenberg et.al. applied an optimization algorithm based on H∞ looping to a quad rotor but the result did not seem more efficient. In [13], Roza and Maggiore implemented linearization and input dynamic inversion to set a effective controller to take a control action in such a way that it is in terms to take an account of various parameters like attitude angle of a system and path parameters. In [14], quad rotor stabilization was implemented by an adaptive neural network scheme in the presence of a sinusoidal disturbance. In [15], a hybrid fuzzy controller with back stepping and sliding mode control applied to eliminate chattering effect of the sliding mode control algorithm successfully. In [16], a fuzzy model based controlled is proposed. The simulation results show that it is better than the conventional discretization methods. In [17], a controller is designed using uncertainty and disturbance estimation. In [18], a wireless camera is used to obtain the status of UAV, and provides feedback to a PD controller.

The mechanism by which the DSM controller gives better results in that the cumulative error signal is always attempted to reduce to zero. In a general purpose delta sigma modulator the normal range of input signal is limited as .55 that is mean value of output of a delta sigma modulator throughout a sample period is almost equal to the analog value of the input signal that is only whenever the normal input signal value is lesser than .55.The reason is the second integrator output gets saturated i.e. exceeds the supply voltage, when the normalized input exceeds 0.55, In the proposed signal dependent DSM, signal dependent feedback is used in order to minimize the integrator outputs.

In this paper. Signal dependant Delta-sigma modulator is proposed and is used as the controller for the UAV. The proposed technique reduces the deviation error to 0.001%. In Fig.4 is shown the basic schematic diagram of UAV in which the encircled portion is the proposed modification and in Fig.5 is shown the block diagram representation of autopilot with proposed DSM controller.

2. Proposed technique

The IInd order, single bit quantizer with unity feedback gain delta sigma modulator is shown in the Fig. 1, and it is the general purpose delta sigma modulator where analog input signal value is x. Thus the sample and hold circuit is used to sample the analog signal with an equivalent sampling period and clock period of delta sigma modulator circuit T_C. D is the delay module which is used to provide one clock pulse delay of delta sigma modulator and the quantizer module is Q with the output range of +1 or -1. Whenever the normal input signal of a single stage delta sigma modulator is greater than .55 then the system becomes unstable. Here x(i) is the analog input signal and also sampled signal to the delta sigma modulator circuit during the sampling period of ith instant. The mean value of the quantizer during the period of kth instant and present period T_U ($T_{U>>}$ T_C) is denoted as y(k). The normal input signal to the delta sigma modulator of kth instant and EX-NOR (k) is the mean value of sampled value of input to the feedback gain. For a classic delta sigma modulator with unity feedback gain more than the unity feedback gain, y (k) is equal to EX-NOR (k) during the period of kth instant.

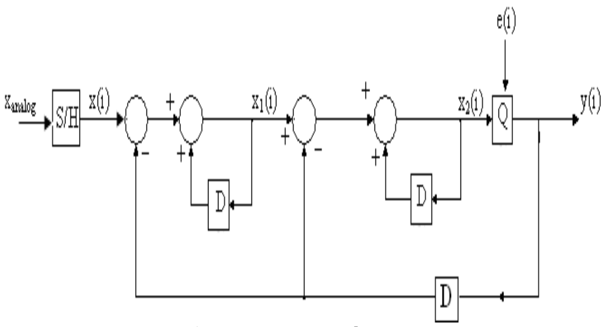

Fig. 1: Conventional DSM.

3. Block diagram of proposed DSM II

The block diagram representation of the proposed delta sigma modulator II is shown in Fig.2. The sample and hold circuit I is used to samples the input signal at a sampling period T_U and is denoted as $(x)T_U$ or simply by x. The normalized input signal (xnor = x/n) can range from -1 to +1 where n is feedback gain constant. Thus the analog signal x is given to the delta sigma modulator as an input signal. The operating time period of a delta sigma modulator is also controlled by the input signal x. The delta sigma modulator circuit is operated by clock signal with the time period of T_C. The n|x| is the feedback gain.The value of n is selected to be greater than unity to satisfy the necessary condition for stability that the input x should be less than the feedback gain. Since the gain element is inserted in the feedback path, the average value of the output during each update period will be divided by the gain of the feedback path. In order to compensate the effect of signal dependant feedback gain, the operating time T_O of the DSM circuit during each update period is varied proportional to x. Therefore,

$$T_O = k \mid x \mid \tag{3.4}$$

Where k is the constant of proportionality. Substituting in equation (3.4) that when $| x |=| x_{\max} |$=n, $T_O = T_U$ results in $k = \frac{T_U}{n}$. Substituting the value of k in equation (3.4), gives the value of TO as;

$$T_O = \frac{T_U \mid x \mid}{n} \tag{3.5}$$

TU and TC are selected such that TU>>TC. As in DSM1, the average values of outputs of the first integrator, second integrator, and quantizer during ith update period are denoted as x1, x2and y respectively and the average value of the quantizer error signal during ith update period is denoted as e. The same notation is followed in other proposed DSMs also. The output of single bit quantizer is +1 or -1 when the DSM is functioning. During a positive transition of update signal, the SR flip-flop is set. When the SR flip-flop is set (phase Φon), the switches s1 to s7 are closed (shown by thin dotted lines) and DSM starts functioning. The DSM output consists of a sequence of pulses of height +1 and -1. The resolution of DSM output, Δy is given by,

$$\Delta y = \frac{T_C}{T_U} n \tag{3.6}$$

The resolution Δy is used to control the operating period of DSM such that the operating period is proportional to |x|. The resolution, Δy is integrated when the R-S flip-flop is set. The integral value of Δy, (Δy)cum is compared with |x|. When (Δy) cum>|x|, the SR flip-flop is reset (phase Φoff) and the switches s1 to s7 are opened. DSM stops functioning and output is zero for the remaining sampling period since the quantizer output is clamped to analog ground through the switch s8. All the integrators, denoted as I1, I2, and I3 are reset to zero and cumulative addition of Δy also stops. Δy is selected such that (Δy) cum is less than |xmax| (n) in a sampling period. During next positive transition of update cycle the DSM operating cycle is repeated.

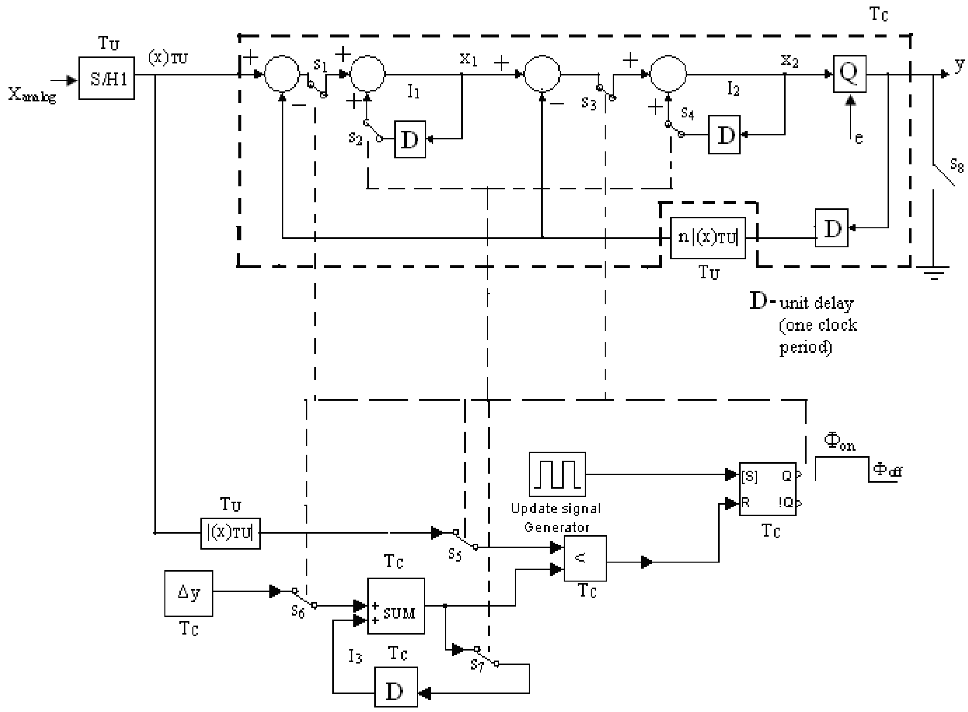

Fig. 2: Proposed DSM of Configuration 2 (DSM2).

The time at which the states of different blocks are updated, is labeled on each block or on set of blocks (shown by thick dotted lines) in Fig.3.2. During each sampling period, the bit stream at the output of quantizer gives the digital representation of input signal. The average value of bit stream at the output during each sampling period (y) is proportional to the analog input signal. The normalized value of y (ny) is equal to the normalized input signal(x/n). The timing–chart of the proposed DSM2 is shown in Fig.3.3. For each update period, TU (which is a constant), the DSM circuit operating time, TO (which is a variable proportional to |x|) will be in the range $0 \leq TO \leq TU$. TU and TC are selected such that TU>>TC.

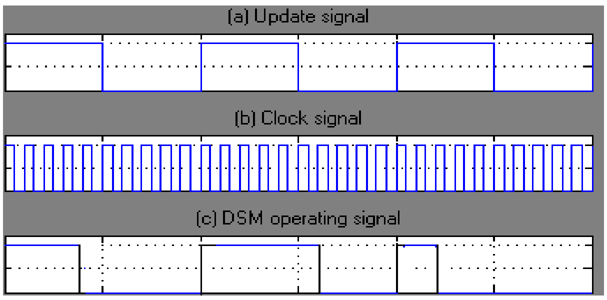

Fig. 3: Timing Chart of Update Signal (Period TU), Clock Signal (Period TC) and DSM Operating Signal (Duty TO).

In the proposed modulator xnorcan vary from -1 to +1 and the modulator is stable for the full range. The input signal is over sampled and DSM input is dc signal for each sampling period. For dc input if the DSM is operated with sufficiently low clock period the average value of the digital output will be a good approximation of the input. This leads to better SNR and power spectral density (PSD) for the complete range of input signal. Hence, the proposed DSM is suitable for industrial applications with control signal of low frequency.

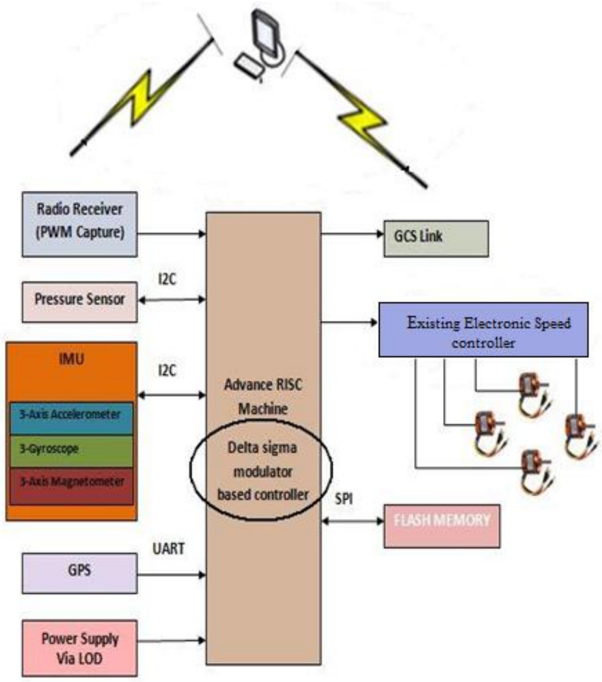

Fig. 4: Autopilot with Proposed Modifications.

In Fig.2, the roll rate controller, pitch rate controller and yaw rate controller of existing Autopilot (PID controllers) are replaced by modified DSM based controllers. K' represents the gain matrix.

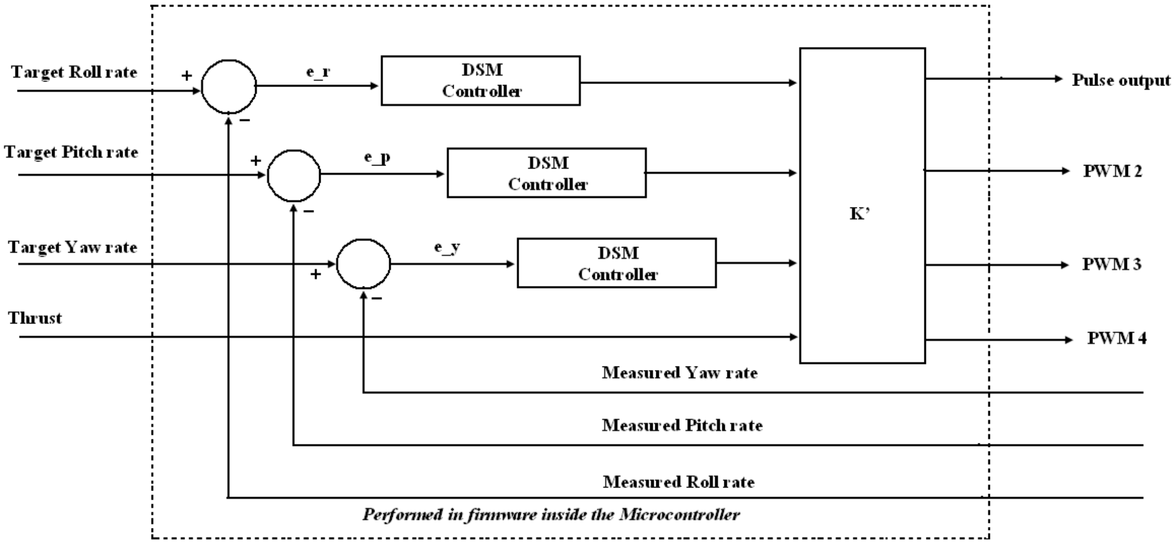

Fig. 5: Autopilot with Proposed DSM Controller.

It is difficult to fix the gain values of PID controller. The attempt is always to optimize overshoot/undershoot, settling time, rise time and steady state error. For dc signal, the DSM gives far better accuracy of 0.001%.The conventional DSM has limited range of input. If the normalized input is above 0.5, the DSM will become unstable. The proposed DSM can operate for the full range of input signal and never become unstable and retains the accuracy of 0.001% for dc signal.

During each sampling period, the bit stream at the output of quantizer gives the digital representation of input signal. The average value of bit stream at the output during each sampling period is proportional to the sampled analog value of the input signal. The normalized value of y (ny) is equal to the normalized input signal (x/n). The proposed modulator increases the input signal range to full scale. The upper bounds of the state variables never overload the quantizer and hence the proposed DSM is stable for the complete range of the input signal. The SNR and PSD are better than the conventional DSM in the overall range.

4. Results and discussion

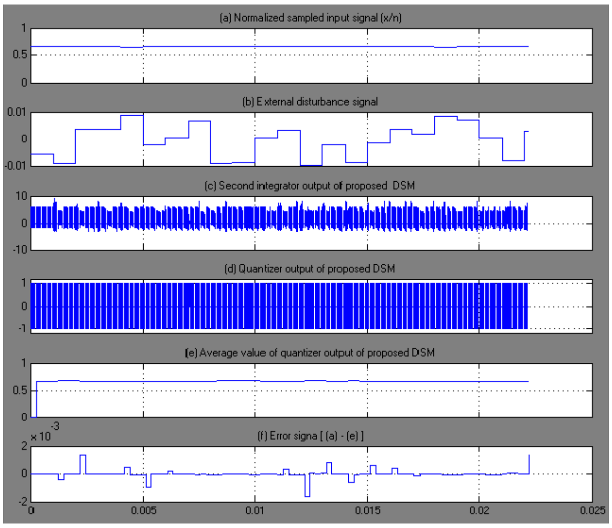

Fig. 6: Simulation Results with DSM Controller.

In this simulation, the altitude variations for a constant PWM signal from the remote controller with external random disturbances is studied. The constant PWM is converted to step input (0.67 V as an example) and is shown in Fig.6 (a). The external random disturbance signal is shown in Fig.6 (b). The second integrator output is shown in Fig.6(c) and is less than 10 V and so the operationalamplifier which is used for the integrator will never be saturated. In Fig.6 (d) is shown the output of the quantizer of the DSM1. The output is a sequence of pulses of amplitude +1,-1, confirming the normal operation of the circuit. There are no continuous ones or zeros (in the expanded view) which signifies instability.

Fig. 6(e) shows the demodulated signal of the quantizer output of DSM. The demodulated signal is the average value of pulses at the output of the quantizer during each update period. It canbe seen that the demodulated signal reproduces analog input signal corresponding to the PWM and is not influenced by the external disturbance signal. In Fig. 6(f) is shown the error signal and the maximum absolute value of the error signal is 0.15mV.

References

[1] John S., “Artificial Intelligent-Based Feed forward Optimized PID Wheel Slip Controller”. AFRICON, Pointe-Aux-Piments., pp. 1-6., September 2013.

[2] Lee K.U., Kim H.S., Park J.B. and Choi Y.H. “Hovering Control of a Quad rotor.” 12th International Conference on Control, Automation and Systems (ICCAS), pp. 162-167., October 2012.

[3] Li J. and Li Y. “Dynamic Analysis and PID Control for a Quad rotor”. International Conference on Mechatronics and Automation (ICMA), pp. 573-578., August 2011.

[4] Runcharoon K. and Srichatrapimuk V. “Sliding Mode Control of Quad rotor”. Proceedings of the International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), Konya.pp. 552-557., May 2013.

[5] Fang Z. and Gao W. “Adaptive Integral Backstepping Control of a Micro-Quad rotor.” Proceedings of the 2nd International Conference on Intelligent Control and Information Processing (ICICIP), Harbin, pp. 910- 915, July 2011.

[6] Diao C., Xian B., Yin Q., Zeng W., Li H. and Yang Y. “A Nonlinear Adaptive Control Approach for Quad rotor UAVs.” Proceedings of the 8th Asian Control Conference (ASCC), Kaohsiung, pp. 223-228., May 2011.

[7] Palunko I. and Fierro R. “Adaptive Control of a Quad rotor with Dynamic Changes in the Center of Gravity.” Proceedings of the 18th IFAC World Congress, Milan, pp. 2626-2631., September 2011.

[8] De Monte P. and Lohmann B. “Position Trajectory Tracking of a Quad rotor Helicopter Based on L1 Adaptive Control.” Proceedings of the 2013 European Control Conference (ECC), Zurich, pp. 3346-3353., July 2013.

[9] Bai Y., Liu H., Shi Z. and Zhong Y. “Robust Control of Quad rotor Unmanned Air Vehicles.” Proceedings of A. Zulu, S. John 556 the 31st Chinese Control Conference (CCC), Hefei, pp. 4462-4467., July 2012.

[10] Tony C. and Mackunisy W. “Robust Attitude Tracking Control of a Quad rotor Helicopter in the Presence of Uncertainty.” Proceedings

of the IEEE 51st Annual Conference on Decision and Control (CDC), Maui, pp. 937-942., December 2012.

[11] Satici A., Poonawala H. and Spong M. “Robust Optimal Control of Quad rotor UAVs.” IEEE Access, 1, pp. 79-93., 2013.

[12] Falkenberg O., Witt J., Pilz U., Weltin, U. and Werner, H. “Model Identification and H1 Attitude Control for Quad rotor MAVs.” Intelligent Robotics and Applications, pp. 460-471., 2012.

[13] Roza A. and Maggiore M. “Path Following Controller for a Quad rotor Helicopter.” Proceedings of the American Control Conference (ACC), Montreal, pp. 4655-4660., June 2012.

[14] Boudjedir H., Yace f, F., Bouhali O., and Rizoug N. “Adaptive Neural Network for a Quad rotor Unmanned Aerial Vehicle.” International Journal in Foundations of Computer Science and Technology, 2, pp. 1-13., 2012.

[15] Zeghlache S., Saigaa D., Kara K., Harrag A. and Bouguerra A. “Backstepping Sliding Mode Controller Improved with Fuzzy Logic: Application to the Quad rotor Helicopter.” Archives of Control Sciences, 22, pp. 315-342., 2012.

[16] Liu Ming-Yong, XuFei, “Intelligent digital redesign of fuzzy-model-based unmanned Aerial Vehicle controllers” IEEE Control Conference (CCC) 32nd Chinese, pp.2251-2255., 2013.

[17] Ashok A., Kumari D., Satish K., Eswar S. and Chandar T.S. “Robust control of UAVs using uncertainty and Disturbance Estimation” IEEE., Industrial Instrumentation and Control(ICIC).International Conference. pp. 434-438, May 2015.

[18] Xian Bin, Lin Yang, Zhang Xu, Can Meihui. and Wang Fu. “Hovering control of a nano quad rotor unmanned aerial vehicle using optical flow.” IEEE, Intelligent Robots and Systems, Control Conference (CCC) 33rd Chinese. pp. 8259-8264., 2014.