International Journal of Soft Computing and Artificial Intelligence, ISSN: 2321-404X, Volume-4, Issue-1, May-2016

ANALYSIS OF TIME DELAY CONTROL SYSTEM FOR UNMANNED AERIAL VEHICLE

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Abstract- The paper describes the time delay control system for unmanned aerial vehicle (UAV) system. The block diagram model for UAV system can be derived from the aero dynamics point of view and the analysis is accomplished with the selection of controller design for UAV system based on time delay function e^{-sT}. The analyses are completed with two cases for time delay control system for UAV. The causes of delays in the controller of UAV are considered. Simulation results show the optimal solution for time delay analysis of attitude command for UAV system.

Index Terms- Time delay control system, Unmanned aerial vehicle, Controller design, Stability analysis and Pade approximation.

I. INTRODUCTION

Atmospheric flight mechanics is a broad heading that encompasses three major disciplines, namely, performance, flight dynamics and aero elasticity. In the past, each of these subjects was treated independently of the other. However, because of the structural flexibility of modern airplanes, the interplay between the disciplines can no longer be ignored. If the flight loads cause significant structural deformation of the aircraft, one can expect changes in the airplane's aerodynamic and stability characteristics which in turn will influence its performance and dynamic behavior. Airplane performance deals with the determination of performance indices such as range, endurance, rate of climb, and take off and landing distance as well as flight path optimization [1-5]. To evaluate these indices, one normally treats the airplane as a point mass that is acted on by gravity, lift, drag and thrust. The accuracy of the performance calculations depends upon how accurately the lift, drag and thrust can be determined. Flight dynamics is concerned with the motion of an airplane due to internally or externally generated disturbances. To describe adequately the rigid-body motion of an airplane one needs to consider the complete equations of motion with six degrees of freedom. Again, this will require accurate estimates of the aerodynamic forces and moments acting on the airplane.

The main feature of UAV is realized - an interactive controlonly in cooperation of the UAV with a ground control station andits central element-the human operator. UAV is of course anautomatic aircraft, designed to fly on a given route and maintainits orientation in space without human intervention, but at thesame time it is ready to respond immediately to control actions ofthe human operator.

The high importance, the responsibility of actionsand theunique properties of a man in non-standard conditions, withimperfection and distortion of information, involve the using ofthe control channels, including the human operator. Aperspective solution, which allows using advantages of a maneffectively, is the using of systems with virtual control circuit,which immerses a pilot in an artificial environment, in which hegenerates control commands for the aircraft, which are adjustedthrough a feedback system. Despite the clear obviousness ofsolutions, there is a number of challenges, which are associatedwith the creation of autonomous remote control system (ARCS).One of these challenges is the emergence of significant timedelays in the control circuit [6].

II. BLOCK DIAGRAM MODEL

The block diagram of time delay control system for UAV is shown in Figure.1. The time delay between the controller and the UAV Dynamics is T=d/v. Therefore, if the controller output is 5°/s, the time taken is 1 s, and the attitude is equal to 5°, then we have a time delay T = 1 s. The loop transfer function is then

$$L(s)=G_c(s)G(s)G_g(s)e^{-sT}$$

$$L(s)=\frac{-10(s+5)(2s+1)}{s^2(s+10)(s^2+3.5s+6)}e^{-sT} \quad (1)$$

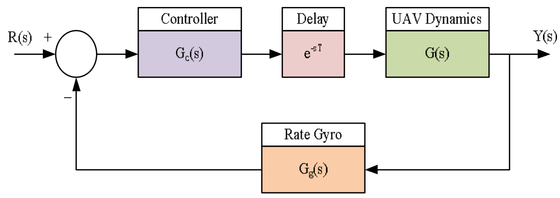

Figure 1: Block Diagram of UAV Time Delay Control System

$$G(s)=\frac{-10(s+5)}{s(s+10)(s^2+3.5s+6)}$$

$$G_c(s)=K_1+\frac{K_2}{s}=2+\frac{1}{s}=\frac{2s+1}{s}$$

$$G_g(s)=1$$

III. TIME DELAY ANALYSIS FOR UAV SYSTEM

A time delay e^{-sT} in a feedback system introduces an additional phase lag and results in a less stable system. Therefore, as pure time delays are unavoidable in many systems, it is often necessary to reduce the loop gain in order to obtain a stable response. However, the cost of stability is the resulting increase in the steady state error of the system as the loop gain is reduced.

The systems considered by most analytical tools are described by rational functions (that is, transfer functions) or by a finite set of ordinary constant coefficient differential equations. Since the time-delay is given by e^{-sT}, where T is the delay, we see that the time delay is non-rational. It would be helpful if we could obtain a rational function approximation of the time-delay. Then it would be more convenient to incorporate the delay into the block diagram for analysis and design purposes.

The Pade approximation uses a series expansion of the transcendental function e^{-sT} and matches as many coefficients as possible with a series expansion of a rational function of specified order. For this research, to approximate the function e^{-sT} with a first order rational function, we begin by expanding both functions in a series (actually a Maclaurin series),

$$e^{-sT}=1-sT+\frac{(sT)^2}{2!}-\frac{(sT)^3}{3!}+\frac{(sT)^4}{4!}-\frac{(sT)^5}{5!}+\ldots(2)$$

And

$$\frac{n_1 s+n_0}{d_1 s+d_0}=\frac{n_0}{d_0}+\left(\frac{d_0 n_1-n_0 d_1}{d_0^2}\right)s+\left(\frac{d_1^2 n_0}{d_0^3}-\frac{d_1 n_1}{d_0^2}\right)s^2+\ldots$$

For a first-order approximation, we want to find n0, n1, d0, and d1 such that

$$e^{-sT}\approx\frac{n_1 s+n_0}{d_1 s+d_0}$$

Equating the corresponding coefficients of the terms in s, we obtain the relationships

$$\frac{n_0}{d_0}=1,\frac{n_1}{d_1}-\frac{n_0 d_1}{d_0^2}=-T,\frac{d_1^2 n_0}{d_0^3}-\frac{d_1 n_1}{d_0^2}=\frac{T^2}{2},\ldots$$

Solving for n0, d0, n1, and d1 yields

$$n_0=d_0$$

$$d_1=\frac{d_0 T}{2}$$

$$n_1=-\frac{d_0 T}{2}$$

Setting d0= 1, and solving yields

$$e^{-sT}\approx\frac{n_1 s+n_0}{d_1 s+d_0}=\frac{-\frac{T}{2}s+1}{\frac{T}{2}s+1}\quad(3)$$

A series expansion of Equation (3) yields

$$\frac{n_1 s+n_0}{d_1 s+d_0}=\frac{-\frac{T}{2}s+1}{\frac{T}{2}s+1}=1-Ts+\frac{T^2 s^2}{2}-\frac{T^3 s^3}{4}+\ldots(4)$$

Comparing Equation (4) to Equation (2), we verify that the first three terms match. So for small s, the Pade approximation is a reasonable representation of the time-delay. Higher-order rational functions can be obtained.

IV. IMPLEMENTATION

Case (a) Suppose the controller is a constant gain controller given by $G_c(s) = 2$. Using the Lsim function, compute and plot the ramp response for θd(t)= at, where a = 0.5°/s. The attitude error after 10 seconds can be determined.

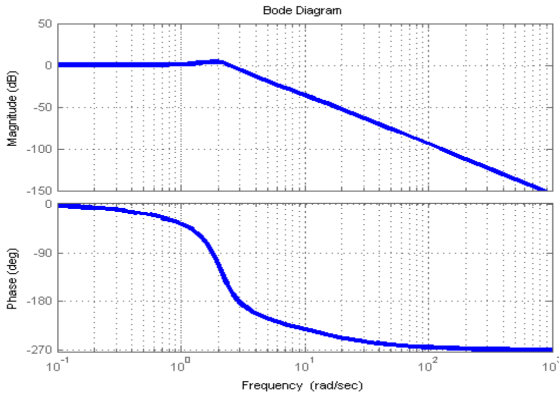

Figure 2: Bode Diagram for Conventional Controller of Time Delay Analysis for UAV

Figure.2 shows Bode Diagram for Conventional Controller of Time Delay Analysis for UAV.Figure.3 illustrates Root Locus for Conventional Controller of Time Delay Analysis for UAV. The roots location and stability analysis is not met.

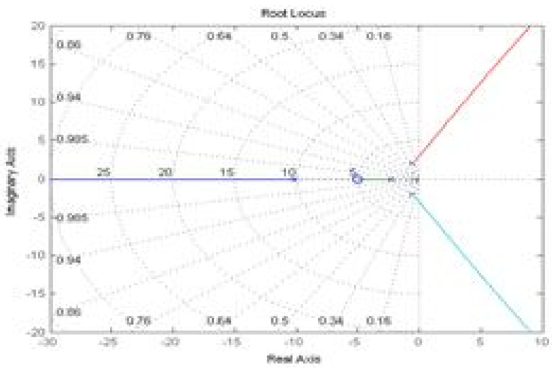

Figure 3: Root Locus for Conventional Controller of Time Delay Analysis for UAV

Figure.4 mentions Nyquist Plot for Conventional Controller of Time Delay Analysis for UAV. According to the Nyquist plot, there is no root enclosed to the (-1,j0) and it may be system unstable with time delay effects. Figure.5 demonstrates the Comparison of Attitude Command for Time Delay Analysis of UAV (Conventional Controller). From this response, the system is not stable because of large time delay error.

The attitude error for case (a) is -0.3001 and we need to try to get the appropriate controller design for time delay control system for UAV.

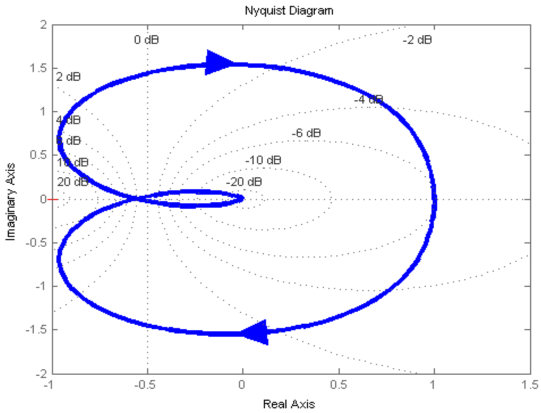

Figure 4: Nyquist Plot for Conventional Controller of Time Delay Analysis for UAV

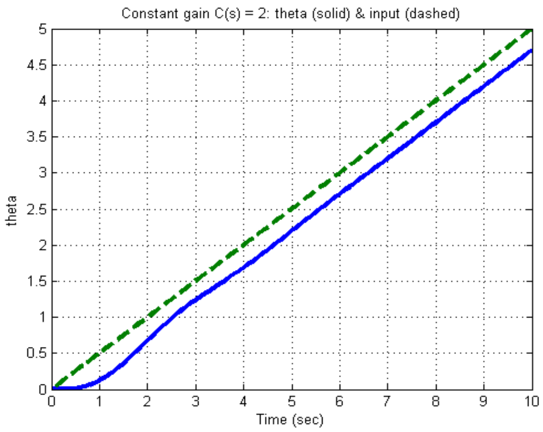

Figure 5: Comparison of Attitude Command for Time Delay Analysis of UAV (Conventional Controller)

Case (b) If we increase the complexity of the controller, we can reduce the steady-state tracking error. With this objective in mind, suppose we replace the constant gain controller with the more sophisticated controller

$$G_c(s)=K_1+\frac{K_2}{s}=2+\frac{1}{s}$$

This type of controller is known as a proportional plus integral (PI) controller. We will compare the steady state tracking errors of the constant gain controller versus the PI controller.

Figure.6 shows Bode Diagram for PI Controller of Time Delay Analysis for UAV.Figure.7 illustrates Root Locus for PI Controller of Time Delay Analysis for UAV. The roots location and stability analysis is met.

Figure.8 mentions Nyquist Plot for PI Controller of Time Delay Analysis for UAV.According to the Nyquist plot, this has root enclosed to the (-1,j0) and it may be system stable with time delay effects. Figure.9 demonstrates the Comparison of Attitude Command for Time Delay Analysis of UAV (PI Controller).

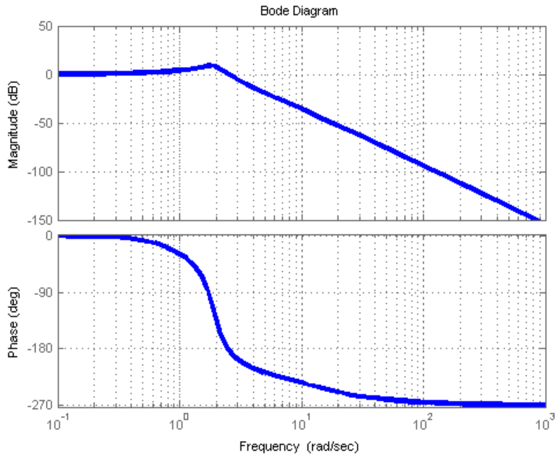

Figure 6: Bode Diagram for PI Controller of Time Delay Analysis for UAV

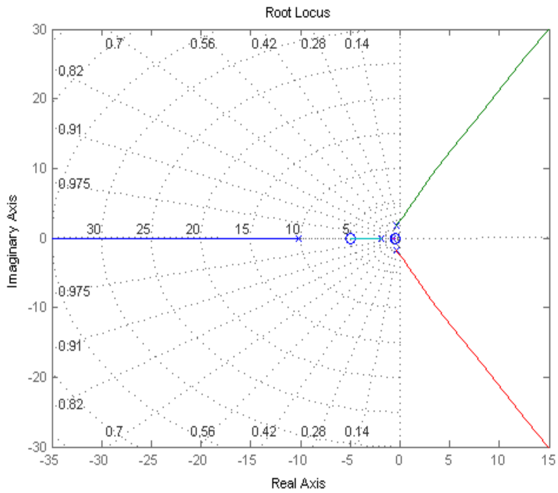

Figure 7: Root Locus for PI Controller of Time Delay Analysis for UAV

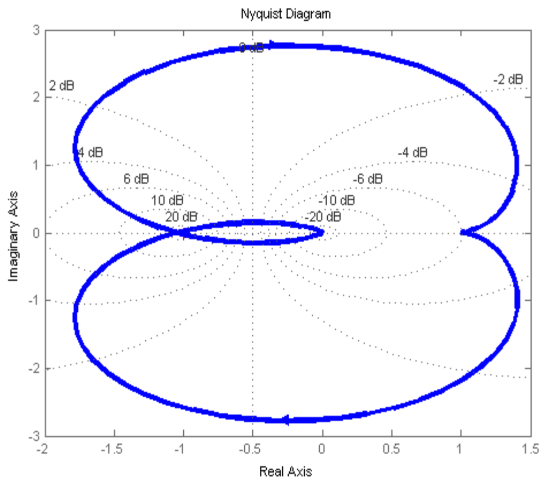

Figure 8: Nyquist Plot for PI Controller of Time Delay Analysis for UAV

From this response, the system is stable because of very small time delay error. The attitude error for case (b) is 0.0074 and we got the appropriate controller design for time delay control system of UAV by using the second method.

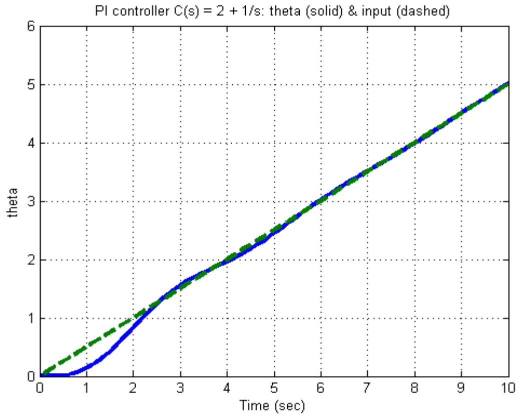

Figure 9: Comparison of Attitude Command for Time Delay Analysis of UAV (PI Controller)

V. RESULTS DISCUSSION

The Bode diagram for the system of case (a) is shown in Figure.2. The phase angle is shown both for the denominator factors alone and with the additional phase lag due to the time delay. The logarithmic gain curve crosses the 0-dB line at ω = 2.5. Therefore, the phase margin of the system without the pure time delay would be 40°. However, with the time delay added, we find that the phase margin is equal to — 24°, and the system is unstable. Consequently, the system gain must be reduced in order to provide a reasonable phase margin. The Bode diagram for case (b) system is exposed in Figure.6. The phase angle is revealed in cooperation for the denominator factors alone and with the additional phase lag due to the time delay. The logarithmic gain curve crosses the 0-dB line at ω = 3. For that reason, the phase margin of the system without the pure time delay would be 40°. However, with the time delay added, we get that the phase margin is equal to 1.4981°, and the system is stable. Consequently, the system gain met in order to provide the stable time delay control system. The necessity of taking into high-speed performance,memory and capacity of digital hardware facilities, realizing the system of autonomous remote control is substantiated.

CONCLUSION

From this study of the causes of the delays in the controller in UAV, we can select only one approach, which can reduce delays in the controller. This approach implies the search of the effective organization of information management and calculation algorithms, the synthesis of control systems, taking into account the information lag, and with the participation of the operator in the control circuit - the development and optimization of the training programs on management of UAV, in order to reduce the response time of the operator while performing tasks.

REFERENCES

[1] Yanhua, Chen Shilu. The MissleAreodynamiccouplong analysis and recombination arethemetic study [J]. Journal of Ballistics, 2003,.15（1）14-15.

[2] Xia Weipeng,LiuShikao. A Missile Recombination Control for Two Channels Cross Combination [J]. Journal of Projectiles, Rockets,2006.26（1）.32-34.

[3] E. Soroka and U. Shaked A recombination approach to the design of the two-degree-of-freedom tracking control systems[A]. Athens, Greece, IEEE, 1986.661-665.

[4] Liu Chenghui. Multivariable process control system recombination theory [M].Beijing , Water Conservancy and Electric Power Press,1999.13-40.

[5] Luo Xutao,Yang Jun. Design of Lateral Flight Control System of Tiltrotor Aircraft by Using Linear Model Following Method [J]. Journal of Projectiles, Rockets,2006.26 (2).374-376.

[6] Zosimovich N. V. Robotized system with combined control to unmanned flying vehicle for operative environmental and ecological monitoring / Air-space technique and technology, 2008. 6 (53). P.40-46.

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