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Review on Aircraft Gain Scheduling

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Abstract – *Flight dynamics is fully nonlinear and the understanding regarding to the flight behaviour is required. Instead of focusing on the local controller, gain scheduling is examined. Gain scheduling method is one of the most popular flight controller as in the gain scheduler are be able to encounter nonlinearity flight dynamics. A short review on both conventional and modern gain scheduling is done by using H2 & H infinity controller as example of conventional scheduler whereas Fuzzy Logic as the modern gain scheduler.*

Keywords: Flight control, gain scheduling, fuzzy logic

1.0 INTRODUCTION

Flight control system is crucial in determining the flying quality of a particular aircraft. Present generation aircrafts are all augmented with sophisticated flight control system especially the fighter aircraft. Most fighter aircrafts are naturally designed to be inherently unstable in which the fighter aircraft could perform extreme manoeuvring flight. Control of aircraft under post stall region is hardly impossible by using linear control system. Hence s newly design of artificial stability have to be implemented.

Since the flight dynamics is nonlinear, the linear control system would leads to limitation in performing level 1 flying quality for fighter aircraft. In order to overcome the nonlinearity of flight dynamics in designing a nonlinear controller, the concept of gain scheduling is employed. In general, gain scheduling design involves three main issues: operating condition under several selective linear region, controller design for the selected linear region, and controller parameter interpolation between linear regions [1, 10]. One of the significant study by Nichols et al. has shown that the implementation of H1 gain scheduling in nonlinear aircraft modal [2] whereas the application of conventional gain scheduling method did show in nonlinear flight missile modal [3].

In contrast, the research done by M. Oosterom, R. Babuska in year 2005 has shown the difficulty in designing a conventional gain scheduler. The main drawback in using conventional gain scheduling is that the change in controller parameter may be abrupt across the region boundary in which lead to unstable performance [1]. Besides, the nonlinearity may not merely constrained by the aeronautical system itself, the aircraft modal, but also due to the subjected external atmospheric conditions according to Fany et al. [5]. Such influences are hardly to be modelled and specifically designed a control system to encounter the atmospheric conditions. Hence more sophisticated gain scheduler have to be considered.

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In order to have better performance in designing the gain scheduler, an adaptive control is proposed and such solution can be found in performing Fuzzy Gain Scheduling. The research done Takagi T. and Sugeno M. [7] on fuzzy control has shown significant improvement in interpolation of parameters in the transition region. By using fuzzy gain scheduling method, the parameter consists in the linear control system design can be represented as part of the fuzzy rule and by setting the inference for decision selection. Similar approach can be found in both researches done by Fujimori et al. [19] and Gonsalves & Zacharias [20]. Both of the findings show similarity in using fuzzy control and the capability in using fuzzy gain scheduling.

To date and to the best of author's knowledge, a simple review on aircraft modal based on conventional and Fuzzy gain scheduling is still insufficient and yet to be discovered. Hence the aim of this article is to compare few significant examples of gain scheduling in aircraft modal and shows its working mechanism in conventional and modern gain scheduling.

2.0 LINEARIZATION

Gain scheduling is a control design for nonlinear system by decomposing few equilibrium points in linear region [10]. Such decomposition depends on the classification of linear system and the main investigation tools is simulation. The major objective in performing gain scheduling is to determine the stability of the associated linear region and approximate the stability of the nonlinear system. Since the nonlinearity is approximated, the boundary conditions have to be concise so that to have a better approximation.

3.0 CONVENTIONAL GAIN SCHEDULING

Conventional gain scheduled is basically referring to the most fundamental control objective in which by observing the norm of certain signals in the control loops. Such approach can be found in H2 and H infinity gain scheduler. H2 gain scheduler is the determination of performance criterion by expressing the minimization of H2 norm in a close loop system [11]. Whereas the H infinity is the minimization of maximum H infinity norm [12]. It is crucial in understanding the H infinity gain scheduler as in the particular gain scheduler is the fundamental of performing scheduling and the understanding regarding to the nonlinearity of the system. According to Doyle et al., the H infinity control problem had been solved and well explain in term of state space formula [13]. This is crucial as in most of the linearized system for aircraft modal are illustrated in term of state space.

Following the research on H infinity gain scheduled controllers for time varying system design [14], in [15] the research done on disturbance study shows significant stability in using convex optimization method. Moreover this lead to the utilization of H infinity controllers in flight control [2, 4] and the stability study of gain scheduling control with highly nonlinear behaviour [5]. Figure 1 shows the fundamental schematic of using conventional H infinity gain scheduler for longitudinal motion mentioned in [4].

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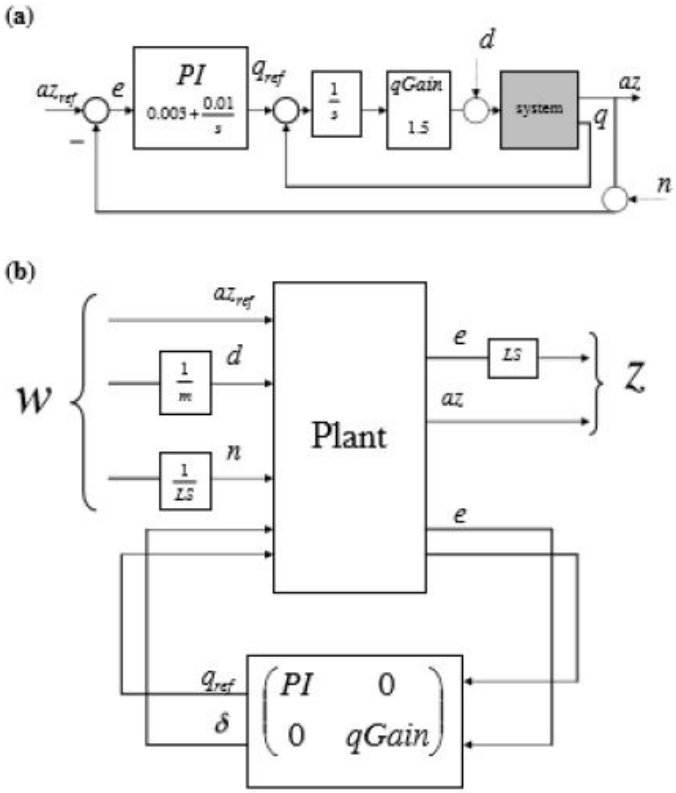

Figure 1: (a) linearization modal at a particular equilibrium point (b) H infinity synthesis [4]

Based on Figure 1(a), the linear system for longitudinal motion is under controlled ny a PI controller and based on [4] the PI controller parameters is scheduled according to the H infinity scheme as shown in Figure 1(b).

4.0 FUZZY GAIN SCHEDULING

Since the study of conventional gain scheduling is extremely difficult and many of the mathematical models for real world is till inherently nonlinear. These nonlinearity made the stability study more complicated and the respond study is no longer a simple task by looking at the general simulation results. In order to simplify to real world model, many assumption has been imposed on the nonlinearity whereas some suggested that using a newly control system in which it could encounter the nonlinearity. Such approach has been done by integrating the theory of Fuzzy Logic done by Takagi T. and Sugeno M. Over past few decades, fuzzy logic has shown its advantages in dealing with linear and nonlinear system. The implementation of fuzzy theory in control engineering shows tremendous outcome and such research can be found in [9, 16].

Beside, integration between conventional PID control and Fuzzy Logic shows better outcome in process control [17, 18]. The Fuzzy Logic act as an intelligent decision making tools where the rules set in Fuzzy Logic are utilized on-line to determine the varying control parameters. This show tremendous advantages in flight control where the flight dynamics itself in nonlinear and without deep insight on each equilibrium points, the Fuzzy gain scheduling controllers are be able to determine the control parameter. The application of Fuzzy gain scheduling in flight

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control can be examine in [6, 9, and 19]. However, it is important to investigate the proper usage of Fuzzy Logic and this included the implementation field of interest, input output membership function and rules based setting.

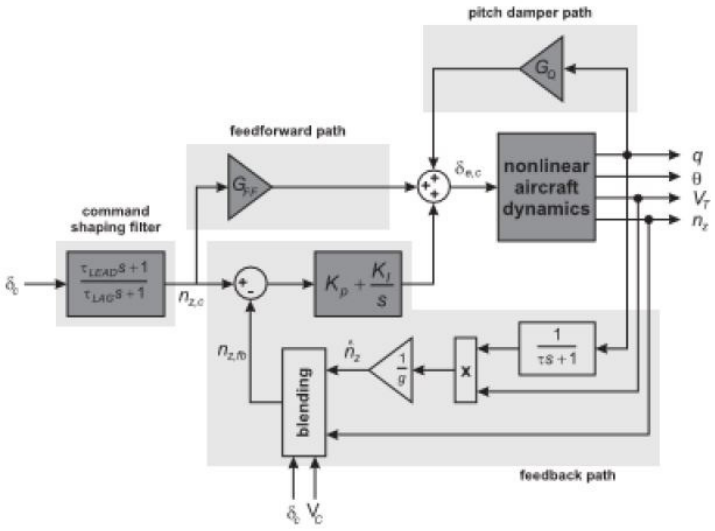

Figure 2: Schematic for aircraft longitudinal motion [6]

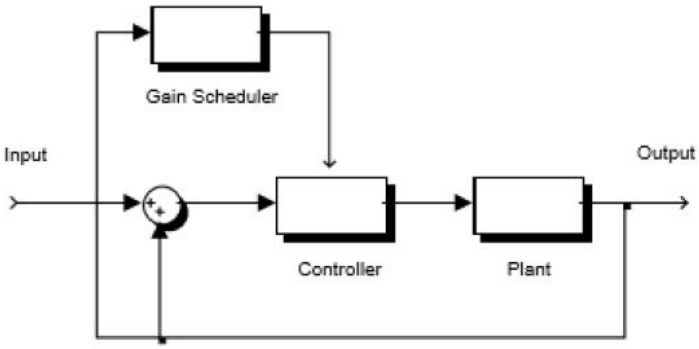

Figure 3: Fuzzy Gain scheduling schematic [8]

Based on [6], the aircraft longitudinal motion is modelled as shown in Fig. 2 and the controller parameters is scheduled according to the Fuzzy Logic as shown in Fig. 3. The controller parameters is interpolated by mean of using Fuzzy Logic and the result obtained in [6] are shown in Fig. 4.

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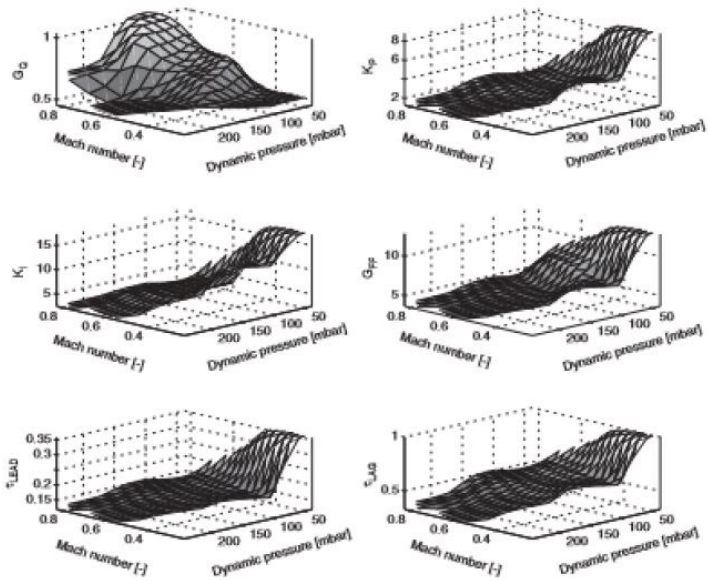

Figure 4: Controller parameters scheduled based on Fuzzy Logic [6]

5.0 CONCLUSION

This paper intend to have a quick review regarding to conventional and modern gain scheduling by using H2 and H infinity controller as example for conventional gain scheduler whereas Fuzzy Logic as the modern gain scheduler. Both of the methods to perform gain scheduled is discussed and related work or research are surveyed. Based on the research work done, the procedure to perform gain scheduling for nonlinear system could share some similarities in which a linear parameter varying system is considered and conventional control system is employed as example, PID control. Besides, the major differences could be found in above mentioned publication is that, the advantageous of Fuzzy gain scheduling over conventional gain scheduling due to its simplicity in application. However, based on the [12 and 13] the understanding to a nonlinear system is required so that the stability and performance of the scheduler can be observed in detail.

As conclusion, there is no ultimate gain scheduler that could fit every nonlinear system. The understanding of the system as well as the controller is crucial and based on the findings, the most appropriate controller is selected and examine its performance. Simulation work is a must to be done in order to study both the system as well as the controller. Yet, future research is more sophisticated and difficult hence with the need of documentation and review study shall be done and documented so that to provide theoretical inquiry for new ideas in gain scheduling.

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