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System Modeling and Artificial Neural Network (ANN) Design for Lateral and Longitudinal of F-16

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Abstract

Today, the classical control methods are still widely used because of their excellent performance in a working environment with conditions of geo-graphical distance. They are suitable for functions of the system: more flexible operating system, easy to perform, less unwanted ricks occur, the efficiency of controlling a system better. Besides the traditional control methods, the author has applied more modern and smarter algorithms such as artificial intelligence to control a system on the ground or a system moving in the air. In this paper, artificial neural network (ANN) is applied for a flight model to demonstrate its effectiveness in all cases. ANN in this article to show off its amazing application for flying devices. This is a useful method because it is highly secure. Simulation is done by Matlab.

Keywords: Linear Quadratic Gaussian (LQG), F-16, Kalman filter.

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1. Introduction

The aviation industry has a special interest by experts in the civil and defense sectors. Humans have long noticed strange flying objects from space, including unidentified flying objects. These objects are carefully identified through security cameras from aircraft or radar devices. A common feature of unidentified flying objects is that they move very quickly if they are detected. This feature has created the impetus for people to discover supersonic flying devices or stealth flying devices. Therefore, it is thanks to the development of science and technology that flying devices in the civil field become more modern [1]. The stability in the control of a flying device has always been thoroughly investigated. These surveys are demonstrated through scientific studies of which this article is an example. Experiments on flying machines have been tried for centuries [2]. They are increasingly modernized with automated technologies. Drones are an example. Control methods for these devices are increasingly new and superior to the classical methods. Control systems supporting flights such as the air traffic station have been optimized with functions of tracking the aircraft through the display screens [3]. To describe the operating states in conventional flying machines, the author has described them as having six degrees of freedom in their motion, including: translational (horizontal, vertical and transverse) motions and rotational (pitch, roll and yaw) motions. Aircraft have three control surfaces (Rudder, Elevator and ailerons). The lateral axis moves from one wing tip to the other to form the horizontal axis of the fuselage. The pitch motion is the angular displacement of this axis. This allows the aircraft to fly higher or lower depending on the pilot's adjustment. The vertical axis goes from the nose to the tail of the aircraft and the movement of this axis is called roll motion. This axis forms the longitudinal axis of the fuselage. Pitch control can be achieved by a method related to the "elevator surface". Similarly, Roll motion is adjusted by "ailerons", yaw control is resolved by rudder surface [4]. The linearization of a system as well as the nonlinear system of F16 is applied in modern algorithms [5-7]. Early research work for aerospace began with looking at how to launch an instrument into the air. These research models are very simple [8] and they are designed to work in tight spaces. Fuzzy methods [9, 10] are also used in the aeronautical field. In particular, PID and Kalman [11] have been applied in UAV systems, which is a step forward in the modernization of equipment. PID controller [12] is used with different levels. In addition, adaptive controller in [13, 14, 15] is implemented in the aircraft parts. It is also used to solve problems in the whole of a system. In surveys [16], data were formed to reflect the security as well as the effectiveness of methods. Methods in [17, 18, 19, 20] are increasingly improved in both hardware and software to better serve a system, including flight systems. Typically, fuzzy method through surveys in [21, 22, 23] has been effective for the manufacturing industry as well as the education sector. What is the motive of this study? This research is useful for inspiring further in-depth machine learning studies with very interesting operational functions. Modern devices like the F-16, for example, need to be equipped with a fresh theory of machine learning and artificial intelligence to increase awareness for readers. Besides, the source of knowledge will become richer with the appearance of modern control methods. The next section includes the following sections of the paper: The title of Part 2 is ‘System modeling linearization’, the title of Part 3 is ‘State space representation of longitudinal and lateral equation’, the title of Part 4 is ‘Simulation results and discussions’. The final part of this paper is ‘conclusion’.

2. System modeling linearization

The control of the F16 is derived from surveys on mathematical models. These mathematical models were established on the basis of physics and they achieved a description of motions of an aircraft. The next part is to investigate the stability of the flight system through a highly secure control scheme: ANN. This plan can change initial characteristics of the system slightly, and plans are programmed to control the operation of the system in accordance with stated expectations, depending on the training levels of an artificial intelligence program. Besides, other aspects must also take into account their effect on the system such as the temperature inside the aircraft which can affect the hardware of controllers, the external environment can also affect the tracking of flight processes of the aircraft. There are many ways for an author to approach models of flying devices so that a paper meets its objectives most effectively. The author has described mathematical settings for a model that is suitable for requirements of the problem [24]. The motion of an aircraft during a flight is the focus of the research to form equations that characterize this form [24]. These equations are based on the laws of physics. According to Newton's law, equations of translational motion, equations of rotational motion are performed synchronously with each other [25]. ANN is given in the context of a working environment where many undesirable effects have occurred, especially in the aviation environment, where it is difficult to have human intervention in the problem of the security of signals. Therefore, this survey is extremely urgent. Previous articles have not addressed this issue. ANN is implemented to control the system as closely as possible. ANN is also a very useful control method in testing properties of objects. It is one of the most modern methods available today.

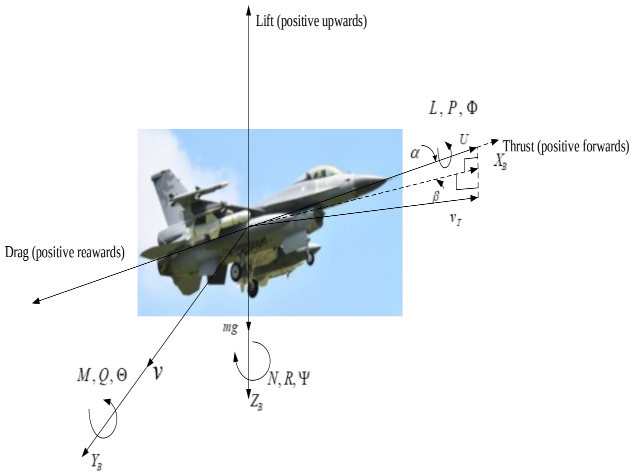

Figure 1. Moments, Euler Angles and Velocities of Aircraft.

Notes: U, V, R are forward, side and yaw velocity; L, M, N are roll, ptich and yaw moments; P, Q, R are angular velocities ; Φ, Θ, Ψ are roll, pitch and yaw angle. This is a type of F16 of any kind. This means that this model is a regular model. The author did not consider the military model or any other specific model. Therefore, this model does not have specific parameters for a particular type of fighter or military aircraft. There was no particular response of F-16 to the use of LQG regulator. This is the same for other systems. They are like that by default. For the translational dynamics:

$$\sum_B F = m\vec{a}_B \quad (1)$$

$$\vec{v}_B = \begin{bmatrix} U \\ V \\ W \end{bmatrix} \quad (2)$$

$$\vec{a}_B = \begin{bmatrix} \dot{U} \\ \dot{V} \\ \dot{W} \end{bmatrix} + \begin{bmatrix} P \\ Q \\ R \end{bmatrix} \times \begin{bmatrix} U \\ V \\ W \end{bmatrix} \quad (3)$$

$\begin{bmatrix} U & V & W \end{bmatrix}^T$ and $\begin{bmatrix} P & Q & R \end{bmatrix}^T$
Represents translatinal and rotational velocities of flight.

$$\vec{F}_B = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + L_{BV} \begin{bmatrix} 0 \\ 0 \\ mg \end{bmatrix} \quad (4)$$

Where $[X \quad Y \quad Z]^T$ acting on Flight and $L_{BV}[0 \quad 0 \quad mg]^T$ represents weight vector

Substituting Eq. (3) and (4) in Eq. (1) gives,

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + L_{BV} \begin{bmatrix} 0 \\ 0 \\ mg \end{bmatrix} = m\left(\begin{bmatrix} \dot{U} \\ \dot{V} \\ \dot{W} \end{bmatrix} + \begin{bmatrix} P \\ Q \\ R \end{bmatrix} \times \begin{bmatrix} U \\ V \\ W \end{bmatrix} \right) \quad (5)$$

After simplifying Eq. (5) given translational dy namics can be achieved for a rigid body.

$$\begin{cases} X = m(\dot{U} - RV + QW + g\sin\theta) \\ Y = m(\dot{V} - WP + UR - g\cos\theta\sin\phi) \\ Z = m(\dot{W} - QU + VP - g\cos\theta\cos\phi) \end{cases} \quad (6)$$

For the rotatinal dynamics of aircraft.

The following moment equations represents the rotatinal form of Newton's second law.

$$\sum \vec{G}_B = \frac{d\vec{H}_B}{dt} \quad (7)$$

$$\vec{H}_B = I_B \vec{\omega}_B \quad (8)$$

$\vec{H}_B$ is momentum of the system

$$\vec{\omega}_B = \begin{bmatrix} P \\ Q \\ R \end{bmatrix} \quad (9)$$

$$I_B = \begin{bmatrix} I_{XX} & I_{XY} & I_{XZ} \\ I_{XY} & I_{YY} & I_{YZ} \\ I_{XZ} & I_{YZ} & I_{ZZ} \end{bmatrix} \quad (10)$$

$\vec{\omega}_B$ and I_B are the angular velocity and Moment of inertia of the system respectively, substituting Eq. (7), (8) and (9) in Eq.(6) give us the Rotatinonal dynamics of the system.

$$\begin{cases} L = I_X\dot{P} - I_{XZ}(\dot{R} + PQ) + (I_Z - I_Y)QR \\ M = I_Y - I_{XZ}(P^2 - R^2) + (I_X - I_Y)PR \\ N = I_Z\dot{R} - I_{XZ}\dot{P} - (I_X - I_Y) + I_{XZ}RQ \end{cases} \quad (11)$$

The above derived translational and rotational equation were used along with disturbance forces and moments, gravitational terms, aerodynamics terms and power terms which are not mentioned here, to get the Longitudinal and lateral directional equations of motion.

3. State space representation of longitudinal and lateral equation

State space is achieved for both longitudinal and lateral motion as follows:

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \end{cases} \quad (12)$$

3.1. Longitudinal dynamics model

The longitudinal dynamics from Eq. (12) are obtained in matrix form as

$$x = [\theta \quad v \quad \alpha \quad q]^T \quad u = [\delta_e] \quad y = [\theta \quad v \quad \alpha \quad q]^T$$

$$A = \begin{bmatrix} 0 & 0 & 0 & 1 \\ -32.1 & -0.013 & -2.66 & -1.18 \\ 0 & -0.0 & -0.67 & 0.93 \\ 0 & 0 & -0.57 & -0.87 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0.0387 \\ -0.0014 \\ -0.1188 \end{bmatrix}$$

$$C = \begin{bmatrix} 57.2958 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 57.2958 & 0 \\ 0 & 0 & 0 & 57.2958 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

The transfer function of Longitudinal Dynamics Model

$$G_1(s) = \frac{-6.807s + 4.606}{s^3 + 0.2s^2 - 0.0528s} \quad (13)$$

$$G_2(s) = \frac{0.0387s^3 + 0.1516s^2 + 4.014s - 2.581}{s^4 + 0.213s^3 - 0.0502s^2 - 0.0006864s} \quad (14)$$

$$G_3(s) = \frac{-0.08021s - 6.4}{s^2 + 0.2s - 0.0528} \quad (15)$$

$$G_4(s) = \frac{-6.807s + 4.606}{s^2 + 0.2s - 0.0528} \quad (16)$$

3.2. Lateral dynamics model

The lateral dynamics from Eq. (12) are obtained in matrix form as

$$x^T(t) = [\phi \quad \beta \quad p \quad r] \quad u^T(t) = [\xi \quad \varsigma]$$

$$A = \begin{bmatrix} 0 & 0 & 1 & 0.078 \\ 0.064 & -0.202 & 0.078 & -0.99 \\ 0 & -22.92 & -2.25 & 0.54 \\ 0 & 6.0 & -0.04 & -0.31 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0.0002 & 0.0005 \\ -0.4623 & 0.0569 \\ -0.0244 & -0.0469 \end{bmatrix}$$

$$C = \begin{bmatrix} 57.29 & 0 & 0 & 0 \\ 0 & 57.29 & 0 & 0 \\ 0 & 0 & 57.29 & 0 \\ 0 & 0 & 0 & 57.29 \end{bmatrix}$$

$$D = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}$$

The transfer function of Lateral Dynamics Model

$$G_1(s) = \frac{3.05s^2 - 0.9491s - 42.13}{s^4 + 2.762s^3 + 8.964s^2 + 16.16s + 0.1754} \quad (17)$$

$$G_2(s) = \frac{0.02865s^3 + 2.988s^2 + 6.296s - 0.05902}{s^4 + 2.762s^3 + 8.964s^2 + 16.16s + 0.1754} \quad (18)$$

$$G_3(s) = \frac{3.26s^3 - 0.4385s^2 - 41.8s + 0.2098}{s^4 + 2.762s^3 + 8.964s^2 + 16.16s + 0.1754} \quad (19)$$

$$G_4(s) = \frac{-2.687s^3 - 6.547s^2 - 4.113s - 2.69}{s^4 + 2.762s^3 + 8.964s^2 + 16.16s + 0.1754} \quad (20)$$

4. Simulation results and discussions

Procedures for carrying out this research work:

Step 1: Set up the model

Step 2: mathematically represent this model in terms of a function or a transfer function

Step 3: build an artificial intelligence algorithm (ANN)

Step 4: simulate the built-in artificial intelligence algorithms according to the function of the model

Step 5: Identify and evaluate this program Model with using Artificial neural network (ANN).

Diagrams of the system using ANN and simulation results are shown Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18.

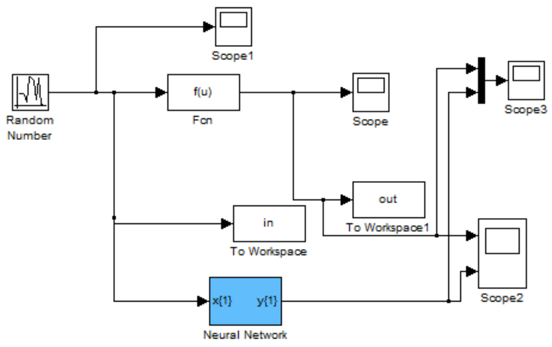

Figure 2. Simulink of Model with Using ANN

Fig 2: the value of f(u)= G_1(u)/ G_2(u)/G_3(u)/ G_4(u): the transfer function of Longitudinal Dynamics Model / Lateral Dynamics Model

The calculation process of the program is carried out as shown in Figure 2

Step 1: The author has assembled the components together as shown in Figure 2

Step 2: The author has loaded the data for the components according to the requirements of the problem.

Step 3: The author has written a program to display a Blue Box.

Step 4: The author has pressed “play” on the control bar to produce the results as shown below.

Part 1: Longitudinal Dynamics Model

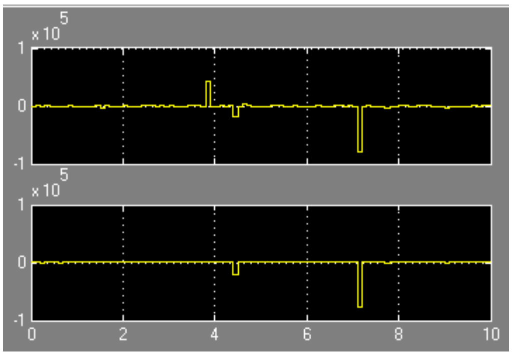

Figure 3. model with using ANN of Scope 2 ‘G_1(u)’

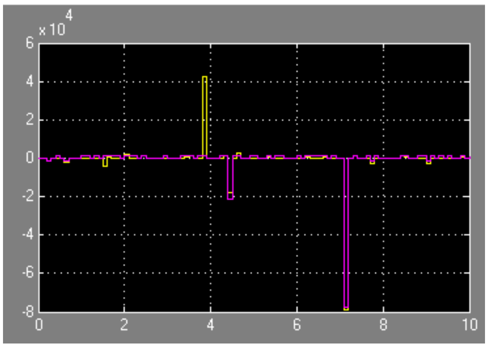

Figure 4. model with using ANN of Scope 3 ‘G_1(u)’

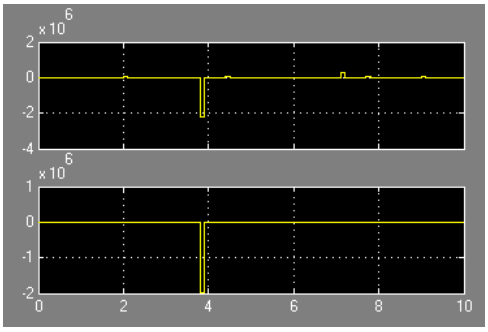

Figure 5. model with using ANN of Scope 2 ‘G_2(u)’

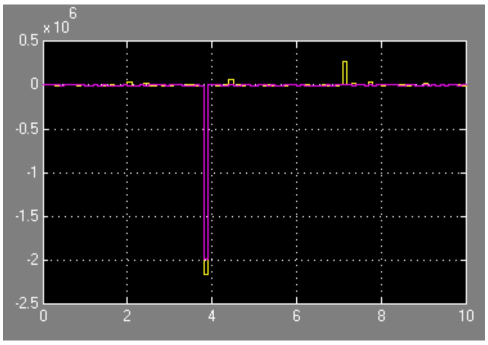

Figure 6. model with using ANN of Scope 3 ‘G_2(u)’

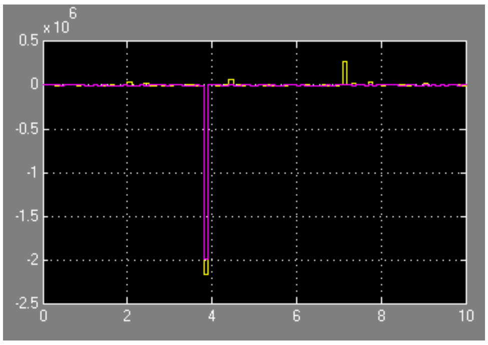

Figure 6. model with using ANN of Scope 3 ‘G_2(u)’

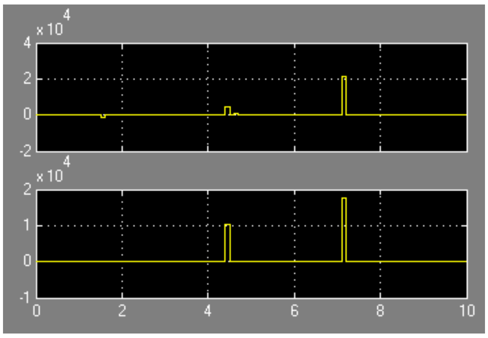

Figure 7. model with using ANN of Scope 2 ‘G_3(u)’

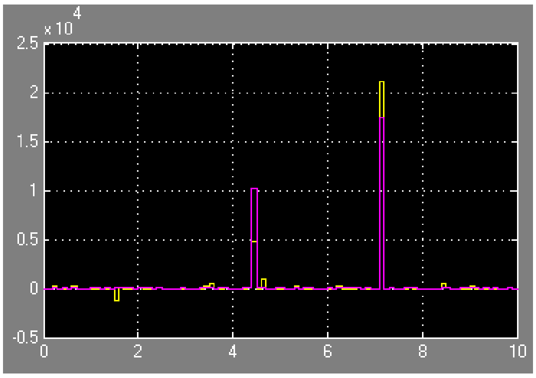

Figure 8. model with using ANN of Scope 3 ‘G_3(u)’

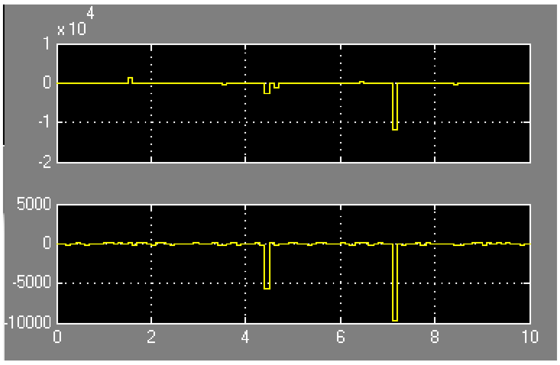

Figure 9. model with using ANN of Scope 2 ‘G_4(u)’

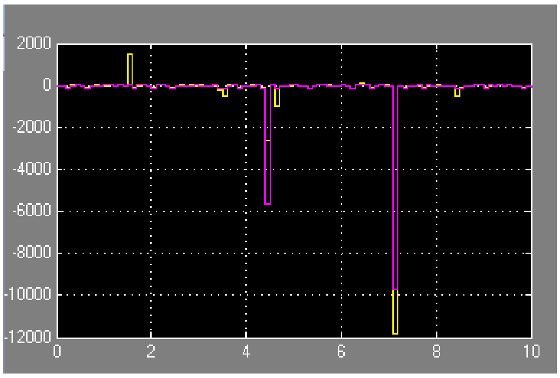

Figure 10. model with using ANN of Scope 3 ‘G_4(u)’

The device that receives the system output signals as shown in Figure 2 is called 'Scope 2' , 'Scope 3'. 'Scope 2' is responsible for receiving signals according to each separate signal port. Meanwhile, 'Scope 3' is responsible for receiving all separate signals into a single signal port. The result of 'Scope 3' is more effective if the purple signal is more common, which means that the separate signals that have shown in 'Scope 2' have almost perfect harmony with each other.

Figures 3, 4, 5, 6, 7, 8, 9, 10 are results of output values of Longitudinal Dynamics Model. Figures 3, 5, 7, 9 are the result of the value of the output without using ANN (above image) and Figures 3, 5, 7, 9 also are the result of the output with using ANN (bottom image). Figures 4, 6, 8, 10 are a composite image of the value of the output without using ANN and the value of the output with using ANN. This result has an almost absolute match between two values above. Therefore, this is considered a successful survey in training the network to achieve desired results.

After reviewing the results of Figures 4, 6, 8, 10, the author found that purple signals were prevalent on the simulation screen. There are only a handful of indications that signals that oscillate at a high value make purple signals unpopular. This shows that the output signals are almost "harmonized" with each other and the application of this controller has achieved the desired results in training the network to shape the initial values.

Part 2: Lateral Dynamics Model

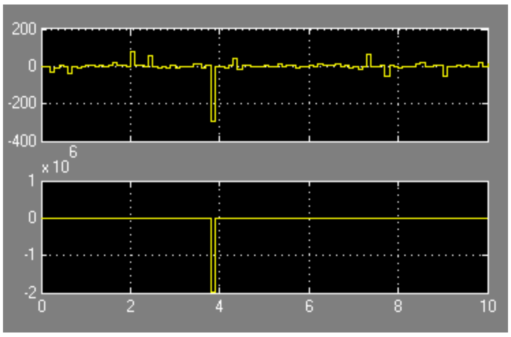

Figure 11. model with using ANN of Scope 2 ‘G_1(u)’

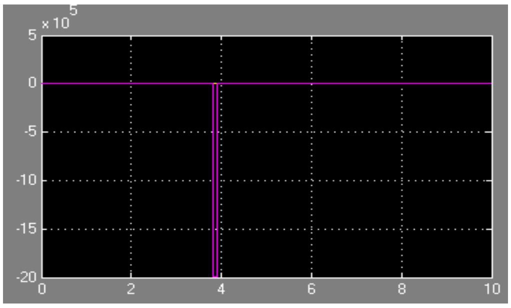

Figure 12. model with using ANN of Scope 3 ‘G_1(u)’

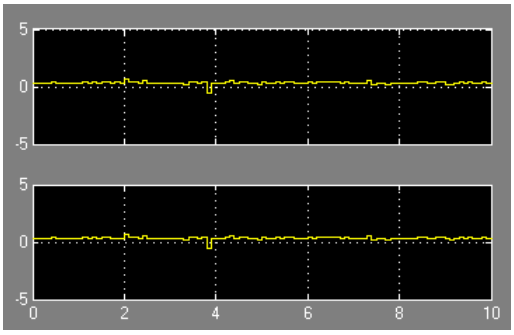

Figure 13. model with using ANN of Scope 2 ‘G_2(u)’

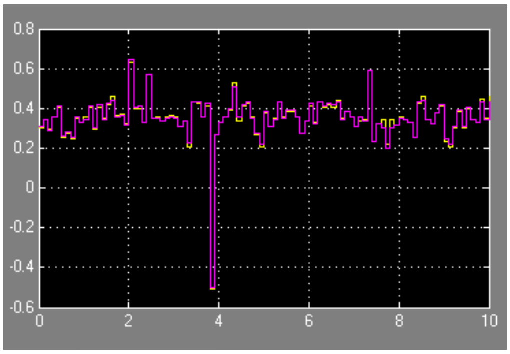

Figure 14. model with using ANN of Scope 3 ‘G_2(u)’

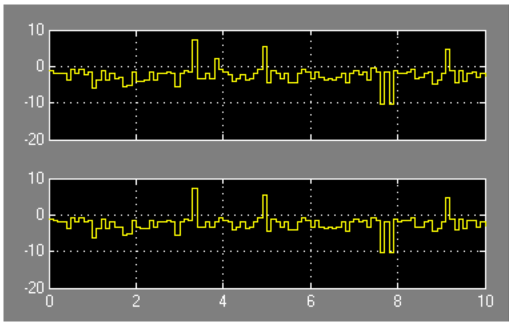

Figure 15. model with using ANN of Scope 2 ‘G_3(u)’

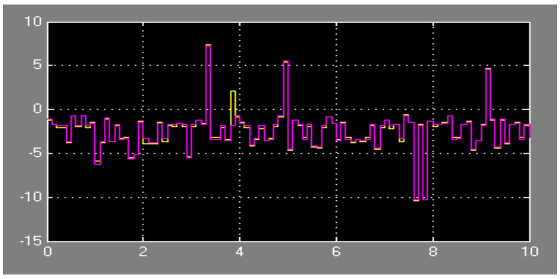

Figure 16. model with using ANN of Scope 3 ‘G_3(u)’

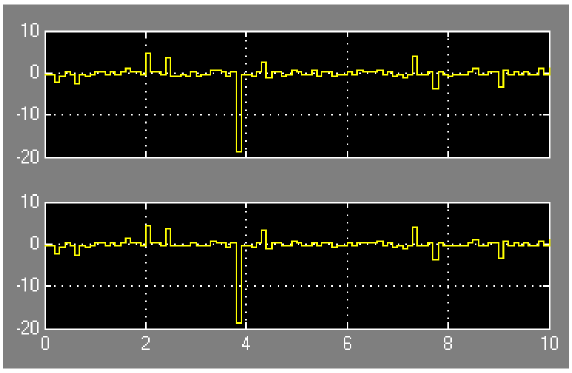

Figure 17. model with using ANN of Scope 2 ‘G_4(u)’

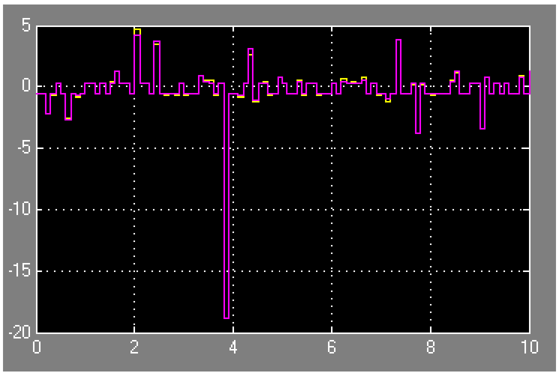

Figure 18. model with using ANN of Scope 3 'G4(u)'

Figures 11, 12, 13, 14, 15, 16, 17, 18 are results of output values of Lateral Dynamics Model. Figures 11, 13, 15, 17 are the result of the value of the output without using ANN (above image) and Figures 11, 13, 15, 17 also are the result of the output with using ANN (bottom image). Figures 12, 14, 16, 18 are a composite image of the value of the output without using ANN and the value of the output with using ANN. This result has an almost absolute match between two values above. Therefore, this is considered a successful survey in training the network to achieve desired results.

After reviewing the results of Figures 12, 14, 16, 18, the author found that purple signals were prevalent on the simulation screen. The indications are that the signals oscillate at a high value that the purple signals are popular. This has a better result than the simulation of part 1. This shows that the output signals are almost "harmonized" with each other and the application of this controller has achieved the desired results in training the network to shape the initial values.

Limitations of this study: studies related to the topic are scarce so the author can refer to them. Recommendation: the author needs the cooperation of experts to have more rich content on this issue. The work of the future includes the development of artificial algorithms at a richer level of genre.

5. Conclusion

To enrich the design processes of control systems in general and the F-16 in particular, the author's choices of control presented above are consistent with the strategies outlined in the introduction. Simulinks for ANN design is performed according to the design process described through the implementation steps. Analysis of the system's effectiveness in thoroughly tested cases. The purpose of this article is for research and educational purposes. The simulation results have been performed in detail. The analysis of simulated parts obtained positive results. ANN can be preferred among other control methods because of its high security. During the implementation of this topic, the simulation results are considered stable for the systems considered by the author. The references listed below are mostly related to aviation equipment. They are relevant to the field under study. These documents have effectively 'supported' for the enrichment of the author's knowledge. The reference type (including set variables) for this system was the only one that was used for this entire paper.

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