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Enhancing the Pitch Control of an Unmanned Aircraft Using PSO Based Intelligent PID Controller

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A B S T R A C T

Pitch, roll, and yaw orientations are primarily relevant to unmanned aircraft control. Unmanned aircraft pitch is significantly impacted by meteorological phenomena including waves and thunderstorms, as well as wind speed and direction, which can cause changes in flight path and attitude. Therefore, a system that guarantees correct pitch maintenance even in the face of system parameter fluctuations is required. In this work, an intelligent PID controller based on PSO was proposed as a means of improving the pitch control of an unmanned aircraft to address this. Unmanned aircraft pitch angle was controlled by a swarm intelligent algorithm that tuned the parameters of a proportional integral and derivative (PID) controller using the particle swarm optimisation (PSO) technique. Both transient and steady-state metrics, such as rising time, settling time, maximum overshoot, and steady-state error, were used to assess the control system's performance by simulation of the model and design with MATLAB/Simulink. The PSO-based PID control system bode plot analysis revealed that it was stable. Additionally, in order to confirm the efficacy of the suggested system, its performance result was compared to that of the classical PID controller used in a prior study for the same system with parameters where Kp = 10.7142, Ki = 2.480, and Kd = 0.92844. This resulted in a rise time of 0.362 seconds, a settling time of 1.48 seconds, a percentage overshoot of 8.51%, and a steady-state error of 0% for the PI controller, and a PID controller with a rise time of 0.814 seconds, a settling time of 0.698 seconds, a percentage overshoot of 27.7% and a steady-state error 0%. The suggested system performed better than the traditional PI and PID control system, according to the simulation analysis, proving that PSO-based PID result compared to result for classical PID, as demonstrated showed that the PSO-based controllers outperform classical PID controllers and enhance the pitch dynamic of unmanned aircraft. Therefore, the application of the suggested scheme will significantly improve the pitch dynamic behaviour of unmanned aircraft even in the presence of system parameter variations.

Keywords: *PSO-based controller, PID Controller, Flight Dynamics, Unmanned aircraft Pitch Control, Flight Control System*

1. Introduction

In aircrafts, the science of its orientation and control in three dimensions is known as Flight Dynamics.Three main factors are taken into account while regulating an aircraft's movement. These are the rotational angles of pitch, roll, and yaw about the three axes around the centre of mass of the aeroplane or aircraft. Roll, which is the same as a ship rolling or heeling, is a rotation about the longitudinal axis that causes the wing tips to move upward or downward and is indicated by the roll or bank angle. Pitch, which is determined by the angle of attack, is a revolution about the sideways horizontal axis that causes the aircraft's nose to go upward or downward. Yaw is a rotation about the vertical axis that causes the nose to sideslip, or shift from side to side.

The fluctuations in angle of attack, sideslip angle, and body axis rotational rates are among the nonlinear aerodynamics that characterise the vast range of flight circumstances that modern aircraft are designed to operate at. Within the field of fluid dynamics, aerodynamics examines the movement of air, especially in relation to solid objects like aeroplane wings. Any aeroplane is subject to two primary aerodynamic forces: lift, which keeps it in the air, and drag, which prevents it from moving. The fundamental idea of flight dynamics is the control and stability of an aircraft's rotation about the pitch, roll, and yaw axes. A flight vehicle's motion in the atmosphere is characterised by flight dynamics. Consequently, it can be seen as a subfield of systems dynamics that examines the systems in a flying vehicle. There are further subdisciplines within the area of flight dynamics that deal with performance, stability and control, and navigation as stated in [1]. Amongst the three major parameters of flight dynamics, aircraft Pitch is the most essential controlled by the rear part of the tail plane hinged to create an elevator, and is measured as the angle between the direction of speed in a vertical plan and the horizontal line. Changes of pitch are caused by the deflection of the elevator, which rises or lowers the nose and tail of the aircraft. The control of an aircraft's take-off timing, flight attitude, flight range and landing angle require an accurate control of the pitch. The pitch angle of an aircraft is controlled by adjusting the angle and equally the lift force of the rear elevator. Adequate control of the aircraft pitch can be used by the flight crew to lessen their workload during cruising and help them land their aircraft during adverse weather condition in the real situation.

The Flight Control mechanism (FCM) is the mechanism used to control a flight. In the early days of aviation technology, fly-by-wire wires and pulleys were employed to manually carry out this function [2]. However, the majority of flights are now autonomously piloted by computers. Many automatic control systems are installed in modern aeroplanes to help the flight crew with navigation, flight control, and improving the aircraft's stability. An autopilot is necessary for the automatic pitch control of an aeroplane, which is a longitudinal problem. An autopilot is a pilot relief device that helps in maintaining an attitude, heading, altitude, or flying in relation to navigation or landing references [3]. According to [4], the purpose of an autopilot electronic system is to provide intelligent and autonomous flight Navigation and Control (N and C) system for autonomous navigation between predetermined waypoints. Often referred to as a pilot assistant, the autopilot supports the pilot on extended flights. It significantly lessens the effort of the pilot by enabling the aircraft to fly straight and level without the pilot's intervention [5]. Certain aircrafts have autopilots integrated into their control systems, which give them access to a full suite of avionics that allow them to fly autonomously to possible and desired destinations. Unmanned Aircraft (UA), Unmanned Aerial Vehicles (UAVs), and Micro Air Vehicles (MAV) are a few common applications for autopilots. The majority of autopilot applications for unmanned aircraft rely on traditional controllers, like PID controllers, to provide sufficient control. Unmanned aircraft autopiloting involves minimal to no human interaction. This indicates that unmanned aircraft can be controlled, to a reasonable degree, by a well-tuned PID controller. In actuality, a UA autopilot generates the control efforts of traditional control surfaces and engine throttle by combining PID feedback controllers, as in the case of Kestrel Autopilot.

The goal of this work is to improve the transient and steady-state response of unmanned aircraft with respect to pitch angle control using PSO based intelligent PID controller, even though there are three main ways for an aircraft to change its orientation relative to the passing air: pitch, roll, and yaw. This goal is achievable by the design of an intelligent-based PID controller that increases an unmanned aircraft's pitch control reaction speed and accuracy.

2. Literature Review

A significant amount of prior research and diverse advancements pertaining to unmanned aircraft pitch control had been done so far and great feat achieved. This highlights the benefits and drawbacks of current unmanned aerial vehicles, UAV, innovations and technologies Chu and Mulder [6]. In a recent study by[7], it was shown that the design of a formation flight control system for aircraft pitch control may utilise the Kalman and PID controller for both pitch angle and speed. In [8], the creation of two full system designs for a guidance, navigation, and control solution for small UAVs was presented. In [9]the authors reported the design choices and autopilot system development for an autonomous Unmanned Aerial Vehicle (UAV) helicopter model. The studies on the contemporary use of autopilot control systems for UAVs that employ sophisticated aircraft pitch control methods like fuzzy logic, neural networks, adaptive control, intelligent control, etc. are the most pertinent of these reviews Pedro et al. [10]. Over the years, a number of unrelenting research efforts have been made to enhance the unmanned aircraft dynamic inversion pitch control system and autopilot pitch control performance K [11].

However, the majority of UAV pitch control still has difficulties with speed and precision, which is an ongoing issue that needs to be solved. This is brought on by insufficient autonomous pitch control of the UAV, particularly in cruising mode and in bad weather, which leads to erratic elevator movements or changes in pitch angle. Consequently, there is sufficient data to conclude that the pitch control issue with UAVs has not yet been entirely resolved, even in the case of the most effective and appropriate dynamic inversion pitch control systems. The aviation industry is still waiting on more advanced and reliable autopilot pitch control technology that can be used to completely solve this issue.

The goal of this work is to enhance the method by Onuora et al. [12] for autotuning PID controller parameters utilising a swarm intelligence based on particle swarm optimisation (PSO) technique. By using this technique, the mismatch that comes with using a traditional PID controller is removed, resulting in better and more optimal pitch angle control for unmanned aircraft. It is anticipated that the PSO-based PID controller, also known as the PSO-PID controller, will increase the UAV elevator's speed or reaction and offer precise pitch control with the lowest possible deviation error.

3. Proposed Method

Figure 1 shows the block diagram for pitch control of an aircraft using PSO tuned PID controller. There are two parts to control system. These parts are classical PID control algorithm and the PSO algorithm that updates the proportional, integral, and derivative (K_p, K_i, K_d) parameters of the PID respectively.

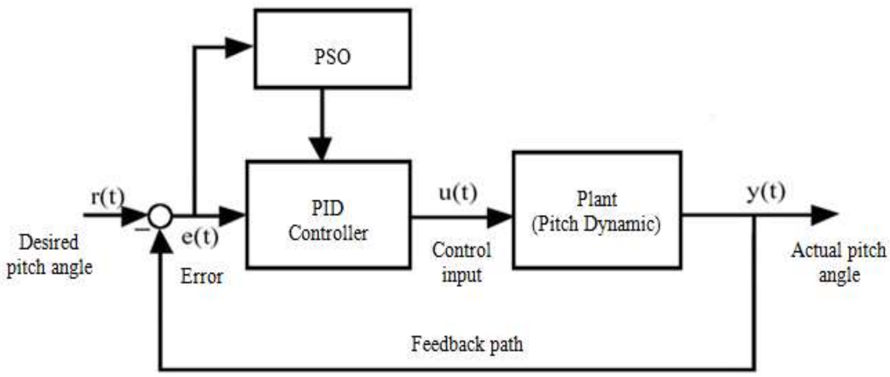


Fig. 1 – Proposed system for unmanned aircraft pitch control

The pitch dynamic is another important parts of the closed loop control system shown in Fig. 1. It is used to describe or represent the plant whose out is to be controlled according to control action (input) or command signal from the PID controller. Hence, this section is divided into three subsections as follows.

3.1 Mathematical model of pitch dynamic

Mathematical equations depicting the dynamics of an unmanned aircraft are derived from the forces and moments operating on the system. L, M, and N in the illustration stand for the components of the aerodynamics moment for the roll, pitch, and yaw axes. The aircraft is impacted by four aerodynamic forces: weight, lift, drag, and thrust.

The thrust is the forward force generated by the power propeller. The drag is caused by air resistance and other aerodynamic elements that work against the aircraft's forward motion. The load on an aeroplane determines its weight. These aerodynamic forces and the force of gravity through the aircraft's centre of gravity (CG) determine the moment of the aircraft (the weight).

The pitch dynamic is considered with the following parameters: x_b , y_b , and z_b defined as the angle of attack, side force, and vertical force and represent the aerodynamic force components.

The pitch angle (or orientation of aircraft) in the earth-axis system and the elevator deflection angle are defined as follows: θ, φ , ϕ for pitch angle, roll angle, and yaw angle with respect to x_b , y_b , and z_b respectively and δe is the sideslip angle. Thus, the mathematical equations for pitch dynamic of an unmanned aircraft can be derived.

The pitch dynamics in terms of force and moment are given by:

$$X - mgS_\theta = m(u + qv - rv) \tag{1}$$

$$Z - mgC_\theta C\phi = m(w + pv - qv) \tag{2}$$

$$M = I_y q + rq(I_x - I_z) + I_{xz}(p^2 - r^2) \tag{3}$$

where X and Z are the aerodynamic propulsive force components acting on the aircraft, M is the pitching moment, S_θ is the reference area of the pitch, C_θ and C_ϕ are the aerodynamic force coefficients, m is the mass of the aircraft, g is the acceleration due to gravity, u is the longitudinal velocity, v is the lateral velocity, q is the pitch rate, r is the yaw rate, w is the normal velocity, p is the roll rate, I_x, I_y, and I_z are the moment of inertia in X,Y,Z axis.

Assuming a symmetric flight condition and constant propulsive force, equations (1) to (3) can be linearized such that initial values for the roll angle, yaw angle, roll rate, yaw rate, normal velocity, and lateral velocity are all equal to zero (i.e. $\varphi_0 = \phi_0 = p_0 = q_0 = w_0 = v_0 = 0)$ resulting in the following equations [4, 12]:

$$X\delta_e \Delta\delta_e = \left(\frac{d}{dt} - X_u\right)\Delta u - X_w \Delta w + (g\cos\theta_0)\Delta\theta \tag{4}$$

$$Z_{\delta_e}\Delta\delta_e = \left[(1 - Z_{\dot{w}})\frac{d}{dt} - Z_w\right]\Delta w - Z_u \Delta u - \left[(u_0 + Z_q)\frac{\mathrm{d}}{\mathrm{dt}} - g\sin\theta_0\right]\Delta\theta \tag{5}$$

$$M_{\delta_e}\Delta\delta_e = -M_u \Delta u - \left[M_{\dot{w}}\frac{d}{dt} - M_w\right]\Delta w + \left(\frac{d^2}{dt^2} - M_q\frac{d}{dt}\right)\Delta\theta \tag{6}$$

where $\Delta\delta e$ is the change in elevator angle and $\Delta\theta$ is the change in pitch angle. Let the change in pitch rate be $\Delta q.$ Hence, the change in pitch rate can be considered as the first derivative of the pitch angle given by:

$$\Delta q = \Delta\frac{d}{dt}\theta = \Delta\dot{\theta} \tag{7}$$

Taking the Laplace transform of Equation (7) assuming zero initial conditions, gives:

$$\Delta q(s) = s\Delta\theta(s) \tag{8}$$

The pitch dynamics can be described in terms of transfer function taken as the ratio of the Laplace transform of change in pitch to that of change in elevator angle given by:

$$\frac{\Delta\theta(s)}{\Delta\delta_e(s)} = \frac{1}{s}\frac{\Delta q(s)}{\Delta\theta(s)} \tag{9}$$

The transfer function of the pitch angle for unmanned aircraft can be defined in terms of Equation (9) by [12]:

$$\frac{\Delta\theta(s)}{\Delta\delta_e(s)} = \frac{1}{s} \times \frac{-\left(M_{\delta_e} + \frac{M_\alpha Z_{\delta_e}}{u_0}\right)s - \left(\frac{M_\alpha Z_{\delta_e}}{u_0} - \frac{M_\alpha Z_\alpha}{u_0}\right)}{s^2 - \left(M_q + M_\alpha + \frac{Z_\alpha}{u_0}\right)s + \left(\frac{Z_\alpha M_q}{u_0} - M_\alpha\right)} \tag{10}$$

Substituting the values of the longitudinal stability derivatives parameters presented in [13] and [12] into Equation (10) gives a simplified numerically represented transfer function for unmanned aircraft expressed by:

$$\frac{\Delta\theta(s)}{\Delta\delta_e(s)} = \frac{11.7304s + 22.578}{s^3 + 6.9676s^2 + 12.941s} \tag{11}$$

Equation (11) is the pitch dynamic, which is the process to be controlled using PSO-PID controller.

1.1. PID based control model

The PID control action is defined according this conventional formula:

$$U(t) = K_p\left[e(t) + \frac{1}{T_i}\int e(t)dt + T_d\frac{de(t)}{dt}\right] \tag{12}$$

where K_p is the proportional gain, $e(t) = r(t) - y(t)$ is the error signal (as in Figure 1), T_i and T_d are the integral time constant and derivative time constant respectively. A transfer function in s-domain can be derived for Equation (12) applying Laplace transform and assuming zero initial conditions as follows:

$$C(s) = \frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) \tag{13}$$

where $U(s)/E(s)$ is the ratio of the control action to the error input and represents the PID controller C(s). The integral gain, K_i and derivative gain, K_d can be defined by:

$$K_i = \frac{K_p}{T_i} \tag{14}$$

$$K_d = K_p T_d \tag{15}$$

The PID controller in Laplace transform is defined by:

$$C(s) = K_p + \frac{K_i}{s} + K_d s \tag{16a}$$

or

$$C(s) = \frac{K_d s^2 + K_p s + K_i}{s} \tag{16b}$$

Then, the PID controller is applied to the system as shown in Figure 2. The resulting mathematical model for the PID based unmanned aircraft control system is defined using the general formula of negative closed feedback loop control system given in equation (17).

$$G(s) = \frac{C(s)\times\Delta\theta(s)/\Delta\delta_e(s)}{1 + [C(s)\times\Delta\theta(s)/\Delta\delta_e(s)]\times H(s)} \tag{17}$$

The feedback measurement gain is assumed to 1 (unity feedback). Thus, the model for the PID based control system is given by:

$$G(s) = \frac{12.01K_d s^3 + (22.302K_d + 12.01K_p)s^2 + (22.302K_p + 12.01K_i)s + 22.302K_i}{s^4 + (0.9523 + 12.01K_d)s^3 + (12.88 + 22.302K_d + 12.01K_p)s^2 + (22.302K_p + 12.01K_i)s + 22.302K_i} \tag{18}$$

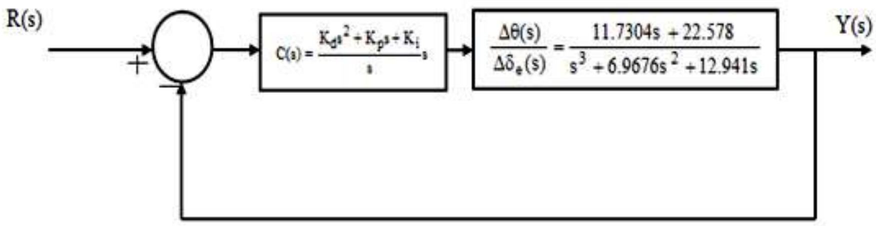


Fig. 2 – PID based control for unmanned aircraft dynamic

3.2 PSO algorithm

The PSO is employed as a technique to tune the PID controller using the model established in Equation (18) to obtained optimized values of K_p, K_i, and K_d. This results in optimal control output (command) for efficient control performance. The algorithm for PSO is defined in the flowchart shown in Figure 3.

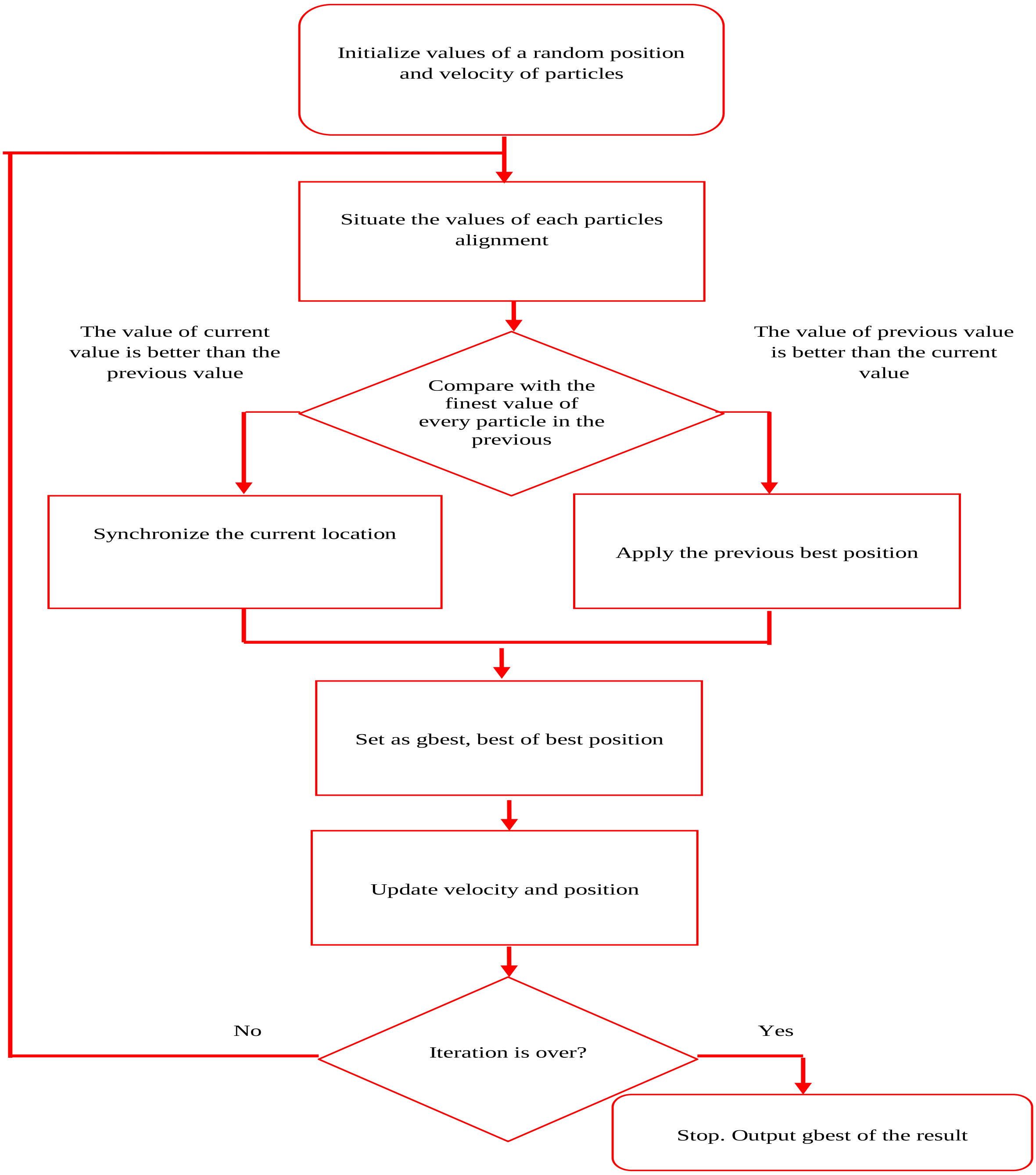


Fig. 3 – PID based control for unmanned aircraft dynamic

In this study, a three-dimensional search space has been created, with the three dimensions standing in for the three PID controller parameters. Every specific point in the search space denotes the precise combination of (K_p, K_i, K_d) needed to produce a certain response. With reference to the previously mentioned time domain parameters, a fitness or cost function has been created. The following defines the MATLAB programme used to accomplish the function:

```
function F= tightnes(Kd,Kp,Ki)

num = [12.01*Kd (22.302*Kd+12.01*Kp) (22.302*Kp+12.01*Ki) 22.302*Ki];

den = [1 (0.9523+12.01*Kd) (12.88+22.302*Kd+12.01*Kp) (22.302*Kp+12.01*Ki) 22.302*Ki];
```

```
G = tf(num,den);

S = stepinfo(T1,'RiseTimeLimits',[0.1,0.9]);

tr = S.RiseTime

ts = S.SettlingTime

Mp = S.Overshoot

Ess = 1/(1+dcgain(T1))

F= (1-exp(-B))*(Mp + Ess)+exp(-B)*(ts-tr)
```

where F is the fitness function, num and den are the numerator and denominator of Equation (18), G is the transfer function given in Equation (18), t_r, t_s, M_p, E_{ss}, and B are the rise time, settling time, maximum overshoot, steady state error, and scaling factor respectively.

The resulting optimal PID controller designed using PSO algorithm is given by:

$$C(s) = 17.1949 + \frac{18.4085}{s} + 6.0696s \tag{19}$$

where $K_p = 17.1949, \mathrm{K_i} = 18.4085 \text{ and } \mathrm{K_d} = 6.0696$. The system parameters are defined in Table 1.

Table 1: Longitudinal Stability Derivative Parameters [13]

Parameter definition		**Components**	
	X	Z	Pitching moment
Rolling velocity	$X_u = -0.036$	$Z_u = -0.0369$	$M_u = 0$
Yawing velocity	$X_w = 0.036$ $X_{\dot{w}} = 0$	$Z_w = -2.02$ $Z_{\dot{w}} = 0$	$M_w = -0.05$ $M_{\dot{w}} = -0.051$
Angle of attack	$X_\alpha = 0$ $X_{\dot{\alpha}} = 0$	$Z_\alpha = -2.02$ $Z_{\dot{\alpha}} = 0$	$M_{\dot{w}} M_\alpha = -8.8$ $M_{\dot{w}} = -0.8976$
Pitching rate	$X_g = 0$	$Z_g = 0$	$M_g = -2.05$
Elevator	$X_{\delta e} = 0$	$Z_{\delta e} = -28.15$	$M_{\delta e} = -11.874$

4. Results and discussion

The outcomes of the MATLAB simulation analysis are shown in this part together with the transient and steady state response performance. The step response performances of the PSO-PID controlled and classical PID controlled unmanned aircraft are presented including the Bode plots in Figure 4-7. The comparison is performed to show the effectiveness of the proposed intelligent based PID controller called PSO-PID control system over the classical PID control algorithm implemented for the same pitch control system of unmanned aircraft in [12] and classical PI control algorithm, which was included in this paper as a classical controller to further validate the effectiveness of the proposed scheme. The numerical analyses of the performances of the systems are shown in Tables 2 for the step responses, while Table 3 shows the numerical comparison of PI, PID and PSO-PID Bode plots.

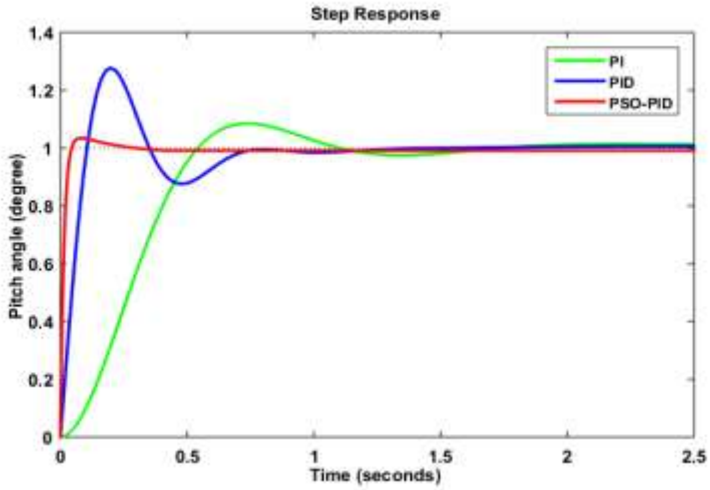


Fig. 4 – Performance comparison of PI, PID and PSO-PID control system

It can be seen that PSO-PID responded faster to a given forcing command (or step input) than the classical PID which is measured in terms of rise time. The PSO-PID control system offered quick convergence measured in terms of settling time compared to the classical PID. Also, the classical PID control system has higher oscillation than the PI and PSO-PID controllers measured in terms of maximum overshoot.

Table 2: Numerical Analysis of Control System Performance

Parameter	**PI controlled system**	**PID controlled system**	**PSO-PID control system**
Rise time	0.362 second	0.0814 second	0.0266 second
Settling time	1.48 second	0.698 second	0.159 second
Maximum overshoot	8.51%	27.7%	3.43%
Steady state error	0	0	0

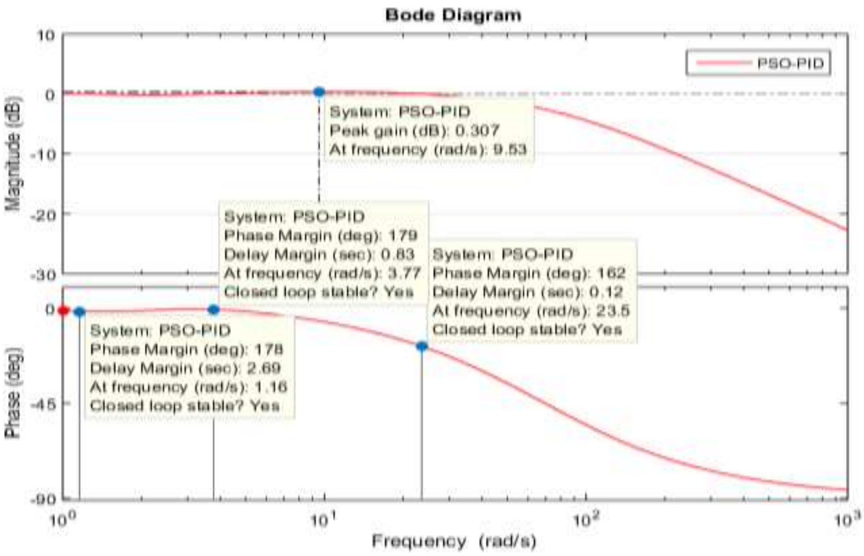
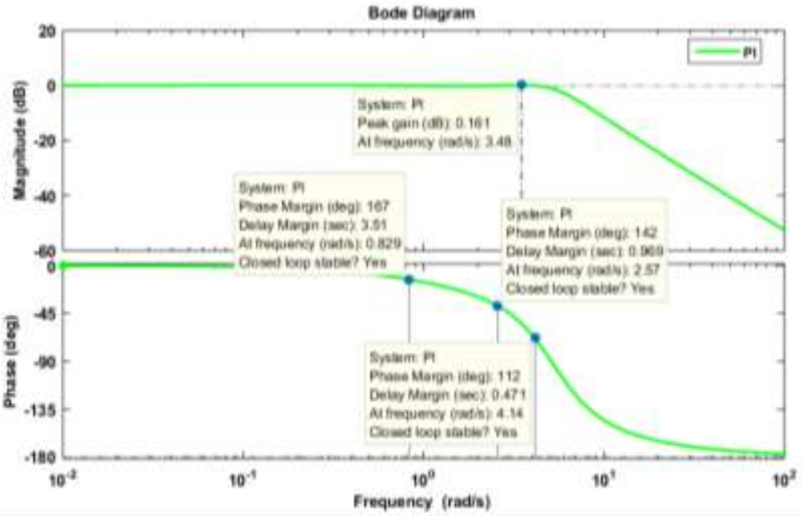


Fig. 5 – Bode plot of PSO-PID controlled system

Fig. 6 – Bode plot of PI controlled system



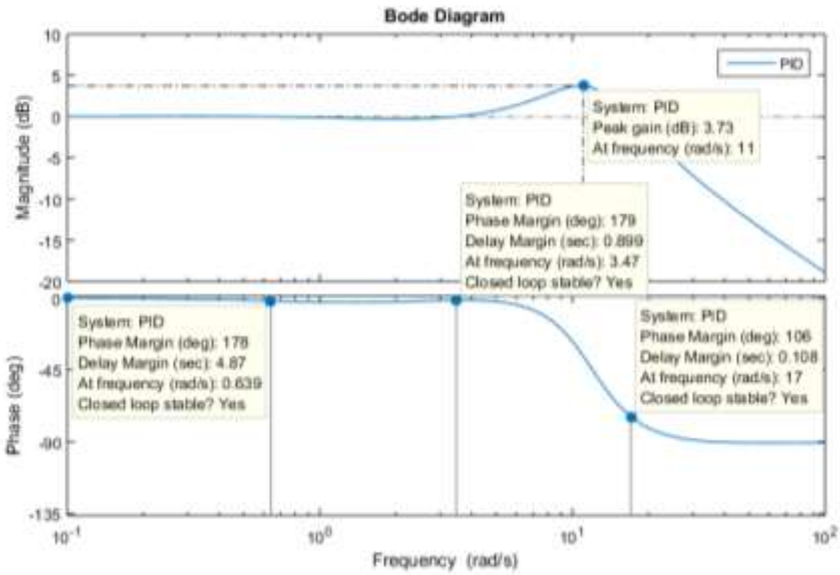


Fig. 7 – Bode plot of PID controlled system

Table 3: Numerical analysis of Bode plots of different system

System condition	Peak gain	Gain margin	Frequency	Time	Remark
Classical PI	0.161 dB	0 dB	3.48 rad/s	0.55 s	System is stable
Classical PID	3.73 dB	0 dB	11 rad/s	0.66 s	System is stable
PSO-PID	0.307 dB	0 dB	9.53 rad/s	0.57 s	System is stable

From Table 3, it can be deduced that the gain of the PI controlled system offered the best peak gain compared to other control systems. It can be deduced that the large gain of the classical PID is as a result of the high overshoot (27.7%). In the case of PSO-PID controlled system, the gain was very much reduced to 0.307 at time 0.57 s. In all the systems, stability is achieved. Generally, the PSO-PID controlled system outperformed the PI and PID controllers by providing improved transient response performance in terms of rise time, settling time and maximum overshoot

Generally, this paper has presented design of an intelligent based PID controller for unmanned aircraft pitch control system. A controller is required by a pitch control system to keep the pitch angle at a predetermined (or set point) (i.e. the expected or desired pitch angle) value. The gains of PID controller were tuned using swarm intelligent algorithm of particle swarm optimization (PSO) and thus the resulting control system is called PSO-PID controller. The PSO-PID controller was applied to pitch control system so as to achieve improved transient response performance. The system performance was analysed in terms of rise time, settling time, overshoot and steady-state error. From the simulation results, the proposed PSO-PID controller was observed to improve the step response performance of the system. In order to validate the effectiveness of the PSO-PID controller, it was compared with classical PI controller and PID controller applied to the same system in [12]. The comparison showed that the proposed PSO-PID outperformed the classical PI and PID controllers. Generally, from the simulation analysis, it was shown that the rise time, settling time, maximum overshoot and steady state error were largely improved by the proposed scheme.

References

[1]. Caughey, D. A. (2011). Introduction to Aircraft Stability and Control Course Notesfor and AE 5070.

[2]. Sas, T., and Cas, T. (2014). Automatic Flight Control Summary, 1–26.

[3]. Myint, H.K. Olo, Z.M. Naing and Y.M Myint (2018).PID Controller for Stability of Piper Cherokee‟s Pitch Displacement using MATLAB. International Conference on Sustainable Development: Issues and prospects for the GMS, China.

[4]. Kada, B., and Ghazzawi, Y. (2019). Robust PID Controller Design for an UAV Flight Control System, II.

[5]. Shaji, J. (2015). Pitch Control of Flight System using Dynamic Inversion and PID Controller, 4(07), 604–608.

[6] Chu, Q. P., and Mulder, J. A. (2015). Flight Envelope Protection.

[7] Lwin, N., and Tun, H. M. (2018). Implementation Of Flight Control System Based On Kalman and PID Controller For UAV, 3(4), 309–312.

[8]. Elkhatem, A. S., & Engin, S. N. (2022). Robust LQR and LQR-PI control strategies Based on adaptive weighting matrix selection for a UAV position and attitude tracking control. Alexandria Engineering Journal, 61, 6275–6292. https://doi.org/10.1016/j.aej.2021.11.057

[9]. Wahab, A. A., Mamat, R., and Shamsudin, S. S. (2013). The Development of Autopilot System for an Autonomous UAV Helicopter Model.

[10]. Pedro, J. I. O. L., Panday, A. A., and Dala, L. A. (2017). A Nonlinear Dynamic Inversion Based Neurocontroller for Unmanned Combat Aerial Vehicles.

[11]. Karlsson, M. (2016). Non-linear Dynamic Inversion.

[12]. Onuora, A. E., Mbaocha, C. C., Eze, P. C., & Uchegbu, V. C. (2018). Unmanned Aerial Vehicle Pitch Optimization for Fast Response of Elevator Control System. International Journal of Scientific Engineering and Science, 2(3), 16-19.

[13]. Wahid, N., Hassan, N., Rahmat, M. F., Mansor, S., and Engineering, E. (2011). Application of Intelligent Controller in Feedback Control Loop for Aircraft Pitch Control Faculty of lectrical Engineering, 3 Faculty of Mechanical Engineering, Universiti Teknologi, 5(12), 1065–1074.