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Object detection by a quad-copter based on advanced microcontroller and improved the PID unit with invasive weed optimization (IWO) algorithm

كشف الهدف بواسطة طائرة رباعية استنادًا الى متحكم متقدم وتحسين وحدة التحكم (PID) بواسطة خوارزمية الاعشاب الضارة (IWO)

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Abstract

One of the best UAVs (unmanned air vehicles) which can be used in many applications such as monitoring and searching of the desired objects is the quad copter.

The current work aims to achieve the flight operation of the quad copter either by the remote control (joystick) or by automatic flight and detection of the desired lading place. In addition , this work involves controlling of the three movements of the quad-copter (roll ,pitch and yaw) using three control unit (PID) that is improved with the Invasive Weed Optimization (IWO) in order to achieve the stabilization for the quad copter.

A quadcopter that has been proposed in this work include a frame (X-configuration), electronic speed controllers, motors, transmitter, GPS module, Lattepanda microcomputer board which is considered a brain of the quad copter, sensors, a receiver ,Batteries and USB microsoft camera that is connected with the frame of a quad copter.

Results that is obtained from the simulation system of the PID controller unit show that there is difference between the parameters and response signals from PID controller without and with optimization by IWO. The invasive weed optimization algorithm reduces the error values of the PID parameters for each of the three motion (roll, pitch ,yaw) and the altitude where the PID controller unit needs less time and less memory through the implementation of the simulation system for the proposed quad copter. On the other hand, the invasive weed optimization algorithm improves the response signal in terms of delay time, rise time settling time and overshoot for each movements of the quad copter .

The results show that the automatic and manual flight operation has been achieved successfully by utilizing all the hardware and software required. Also, the desired target (Mark X) has been detected from five meters high from the ground according to the deep learning algorithm through the matlab program.

Key Words: Quad copter, Deep neural network (D.N.N), Invasive Weed Optimization Algorithm (IWO) , Lattepanda board , object detection , auto pilot quad copter .

الخلاصة

تعتبر المروحية الرباعية (الكوادكوبتر) واحدة من أفضل الطائرات بدون طيار التي يمكن استخدامها في العديد من التطبيقات مثل المراقبة والبحث عن الاهداف المطلوب.

يهدف العمل الحالي إلى تحقيق عملية الطيران للطائرة الرباعية إما عن طريق التحكم عن بعد باستخدام (عصا

التحكم) أو عن طريق الطيران التلقائي والكشف عن الهدف المطلوب للهبوط . بالإضافة إلى ذلك ، يتضمن هذا العمل التحكم في الحركات الثلاث للمروحية الرباعية والتي تشمل زاوية البساط (roll) و زاوية العطوف (pitch) و زاوية الانعراج (yaw) باستخدام ثلاث وحدات تحكم نوع (PID) حيث تم تحسين هذه الوحدات باستخدام خوارزمية الاعشاب الضارة (IWO) التي تعمل على جعل الطائرة الرباعية اكثر استقرارا.

تشتمل الطائرة الرباعية التي تم اقتراحها في هذا العمل على هيكل الطائرة الرباعية ويكون (شكل X) ، أجهزة تحكم السرعة الإلكترونية، المحركات، نظام تحديد المواقع (GPS)، المتحكم المتقدم (Lattepanda) والذي يعتبر دماغ المروحية الرباعية أجهزة الاستشعار، جهاز الارسال والاستقبال ، بطاريات وكاميرا (USB Microsoft) التي تكون متصلة مع هيكل الطائرة الرباعية.

حيث أظهرت النتائج التي تم الحصول عليها من نظام المحاكاة لوحدة تحكم (PID) أنه عندما تم تحسين وحدة التحكم (PID) مع خوارزمية تحسين الأعشاب الضارة (IWO) ، كان هناك فرق واضح بين عوامل وحدة التحكم PID controller (Kd ،Ki ،Kp) وإشارات الاستجابة التي تم الحصول عليها من تحسين وحدة التحكم مع خوارزمية (IWO) عن عوامل PID و إشارات الاستجابة التي تم الحصول عليها من وحدة تحكم (PID) وحدها دون تحسينها مع خوارزمية الأعشاب الضارة (IWO). حيث تعمل خوارزمية تحسين الاعشاب الضارة على تقليل قيم الخطأ لعوامل (PID) لكل حركة من الحركات الثلاثة للطائرة الرباعية(زاوية البساط وزاوية العطوف وزاوية الانعراج) و من ناحية أخرى . تعمل خوارزمية (IWO) على تحسين إشارة الاستجابة من حيث وقت التأخير ، ووقت الارتفاع و وقت الاستقرار .

أظهرت النتائج أن عملية الطيران اليدوي والتلقائي قد تم تحقيقها بنجاح باستخدام جميع الأجهزة والبرمجيات المطلوبة لهذا الغرض . أيضا ، تم الكشف عن الهدف المطلوب (علامة X) على ارتفاع خمسة أمتار من الأرض وفقا لخوارزمية التعلم العميق (Deep neural network(D.N.N)) وتعتمد هذه الخوارزمية على ايجاد نقاط مشتركة بين صورة الهدف المطلوب وبين صورة المصدر (المرجع) خلال استخدام برنامج Matlab.

1-Introduction

A quadcopter is a plane with four engines that can fly vertically up or down. In last decades, because of great achievements in technologies such as electronics, microcontrollers, motors, sensors and software, an opportunity of building small unmanned aerial vehicles (UAVs) became wide world available which can be easily built [1].

The UAVs are gaining significant importance at the current time because of the urgent need for them in different fields of life. It can be distinctly see from the applications of UAVs, it is utilized in the fields of the oil & gas in the search operations, in both onshore and offshore settings with regarding to pipelines, structures and flame piles as well as it is utilized in industry of the mining for the aerial mapping, surveying and mining exploration [2]. Additionally, it is utilized in the power industry for testing of the transmission lines. These applications contribute in taking away workers from risky places and facilitate the monitoring strategy. Mini quad copters has several advantages as compared to the other types of choppers. For instance, they are largely utilized in the engineering, mapping, meteorology, aerial photography, surveying and also in entertainment [3].

Many researches have been proposed on various issues around quad-copters either count on simulation, or covering hardware design part. Where, R. Omar, et.al. in 2013 [4] presented a remote control system for quadcopter. By FY90 controller and IMU 6DOF sensor, the conditions of the quad-copter balancing are sensed. Arduino Uno board is utilized to process all sensors' signals in order to control Quadcopter propellers. Also where, F. Syam, et.al. in (2014) [5] presented simulation and experimental action of the quadcopter model. The main aim is creating a simulation and experimental for movements of the aircraft for multi-rotor quadcopter. M. Alsaedi and et.al. in (2017) [6] presented a development and integration of an X-configuration quad copter with an IP camera for object detection based on the color of an object. A KK2 microcontroller is used to control the quadcopter movements. This work aims to achieve the flight operation of the quad copter either by the remote control or by automatic flight and detection of the desired lading place.

In addition , this work involves controlling of the three movements of the quad-copter (roll ,pitch and yaw) using three control unit (PID) that is improved with the Invasive Weed Optimization (IWO) in order to achieve the stabilization for the quad copter. Figure (1) shows the proposed design of the quadcopter which is used in this work.

Figure (1) : The proposed quadcopter designed

2) Invasive Weed Optimization (IWO) Algorithm

IWO is a continuous stochastic numerical algorithm inspired from the "weed colonization" that simulates the natural behavior of seeds in colonization and finding suitable places for growth and reproduction. This algorithm was invented by the Mehrabian and Lucas in 2006. Which has displayed effective results with several workable applications such as adaptive beam forming, optimal positioning of piezoelectric actuators, analysis of electricity markets dynamics, adaptive control and developing a recommender system and tuning and optimization of a robust controller. The equation of the standard deviation is given as [7].

$$\sigma_{iter} = \frac{(iter\ max - iter\ )^{pow}}{iter\ max}\ (\sigma max - \sigma_{min}) + \sigma_{min} \qquad (1)$$

where σ represents the standard deviation of the random function $iter_{max}$ is the maximum number of iteration, σ_{iter} is the standard deviation at the present iteration and pow is the non-linear modulation index. The aim is to reduce the standard deviation σ for a weed when the objective function value of a particular weed nears the minimum objective function value of the current population, so that the weed disperses it's seeds within a small neighborhood of the suspected optima. Equation (2) will be described the scheme by which the standard deviation (σi) of the ith weed is varied.

$$\sigma_i = \sigma_{final} + (1 - e^{-\Delta f_i})(\sigma_{initial} - \sigma_{final}) \qquad (2)$$

where $\Delta f = \left| f(\vec{w}_i) - \overrightarrow{f(w_{best})} \right|$, so when $\Delta f_i \rightarrow 0$ then $\sigma_i \rightarrow \sigma_{final}$

As $\sigma_{final} \ll \sigma_{initial}$, so when $\Delta f_i \rightarrow 0$. The i_{th} weed is in close proximity of the optima ,then the standard deviation of the weed becomes very small resulting in dispersal of the corresponding seeds within a small neighborhood around the optima. Thus in this scheme, instead of using a fixed σ for all weeds in a particular iteration. So this scheme in one hand increases the explorative power of the weeds and on the other creates some probability for the seeds dispersed by the undesirable weeds (the weeds with higher objective function value) to be a fitter plant [8].

Three control unit (PID controller) are used in this work. The Proposed PID controller optimized with invasive weed optimization (IWO) Algorithm is shown as in figure (2).

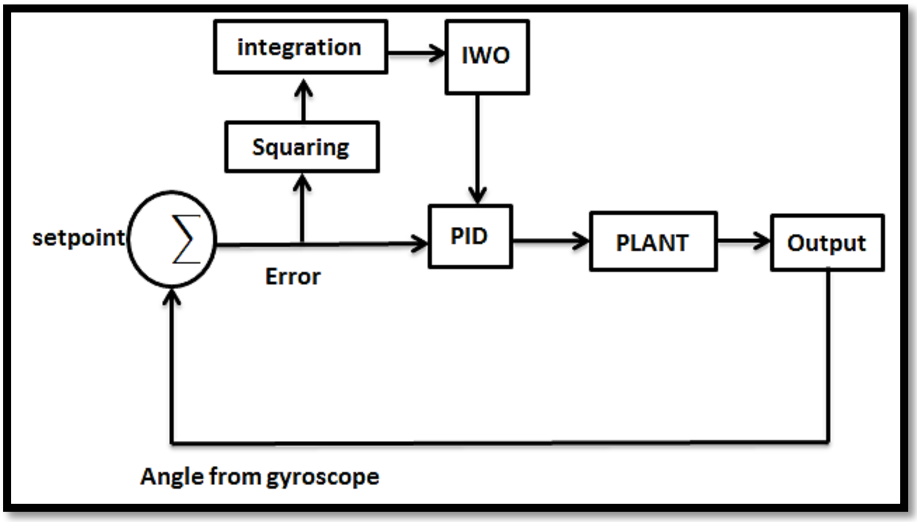


Figure (2) : Proposed PID Controller Optimized with invasive weed optimization (IWO) Algorithm

3- Automated and Manual Operations of the Proposed Quad copter

The quadcopter can fly in two modes: either by automated flight operation or by manual operation through the remote control (joystick). In this work, both of these operation is implemented.

3.1 Automatic Flight operation

The aim of this work is tracking the quad-copter for the target location with the help of microcomputer lattepanda board , Ublox Neo-M8N GPS and microsoft lifecam USB video camera by using the object detection concept (using deep learning algorithm).

When the quadcopter starts the takeoff to the desired area, either by remotely control (joystick) or by the autopilot, the GPS device begins the search process for the desired target by the camera.

During the Lab view program, latitude and longitude are determined by the Neo-M8N GPS. When the quadcopter is running, the Neo-M8N GPS will begin to send the continuously changing location. When the quad copter reaches the required area, the microcontroller Arduino Leonardo which is built-in within the lattepanda board gives indication to the processor for completing its access to the desired area.

Through this indication, the lifecam camera which is connected with the quadcopter will be run during the Matlab program. Then, the lifecam camera starts for searching for the desired target (mark X) and when it arrives to the intended target will get a comparison between the target image that is obtained and the reference image by using the deep learning algorithm. The main component of the quadcopter is the autopilot board which decides how much power is needed for each engine.

A graphical user interface (GUI) is used with the Lab View program for both the automatic and manual controlling in the quadcopter. Two points appears on the graph through the GUI, the first point represents as a point from the receiver of Ublox Neo-M8N GPS. This point shows the quadcopter position. The second point represents as a point of the target, so that it shows the position of the target(x). In the system, the altitude, latitude and longitude are selected for each point.

Figure (3) shows the graphical user interface for 3-D location that is designed by the lab view for the proposed system. From the 3-D location GUI one can give the target position, quadcopter position and GPS points. Where each of latitude, longitude and altitude are specified by GPS for the position of the quadcopter, and as for the position of the target each of the latitude, longitude and altitude are given by the controller. Also, from the GUI one can choose the flight for the quadcopter either autopilot or manual operation.

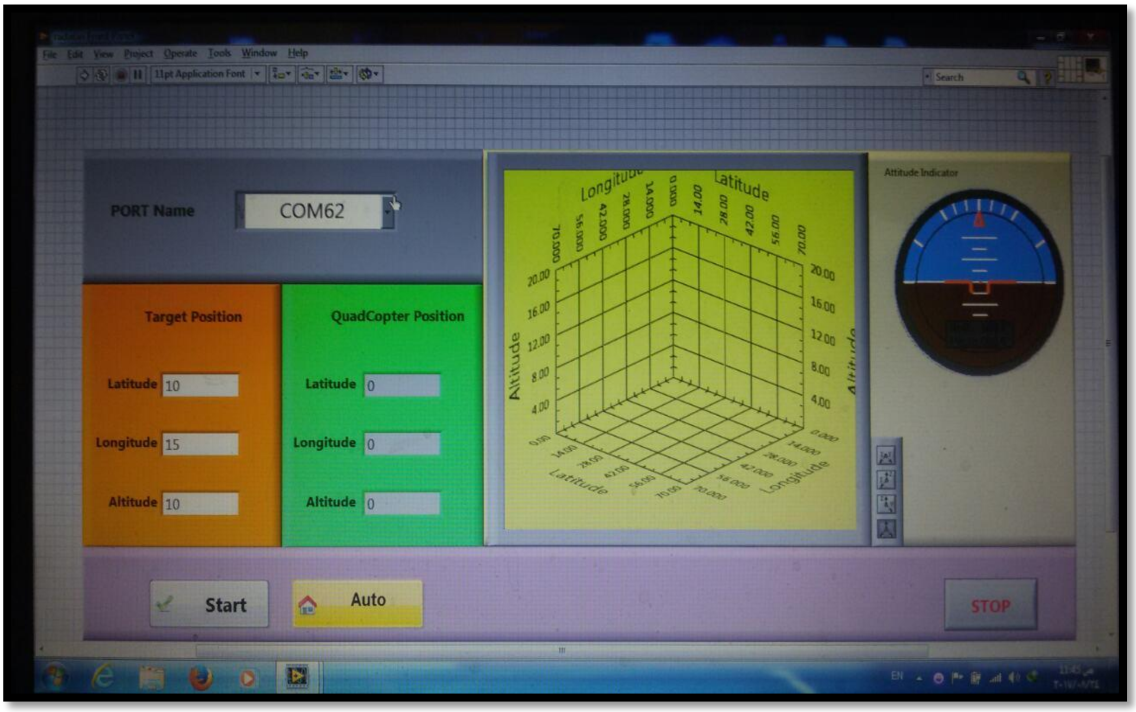


Figure (3) : GUI for 3-D location with lab view

3.2 Remote Control Operation (joystick)

In this case, Radio signals are transmitted from the control station and received by the receiver that interfaced to the autopilot.

In the proposed system, the signal is sent from the joystick (remote control) by the transmitter of the NRF24L01 to the receiver of the NRF24L01(which is connected with Lattepanda board that is considered heart of the quadcopter).

Three control unit PID controllers are used to dominate the three movements of the quadcopter. The first movement is the roll that determines the left and right movement of a quadcopter, the second movement is the pitch that determines forward and backward movement of a quadcopter and the third movement is the yaw that determines the turning of a quad copter's head either to the left or to the right.

After the control signals have been calculated through the three PID controllers for each of the yaw, pitch and roll, these three control signals will be collected with the signal of the throttle and send to the quad copter through the remote control unit (joystick) to determine the speed of each motor to raise the quad copter .A general block diagram for the system of a quadcopter with the three PID controller is shown in the figure (4).

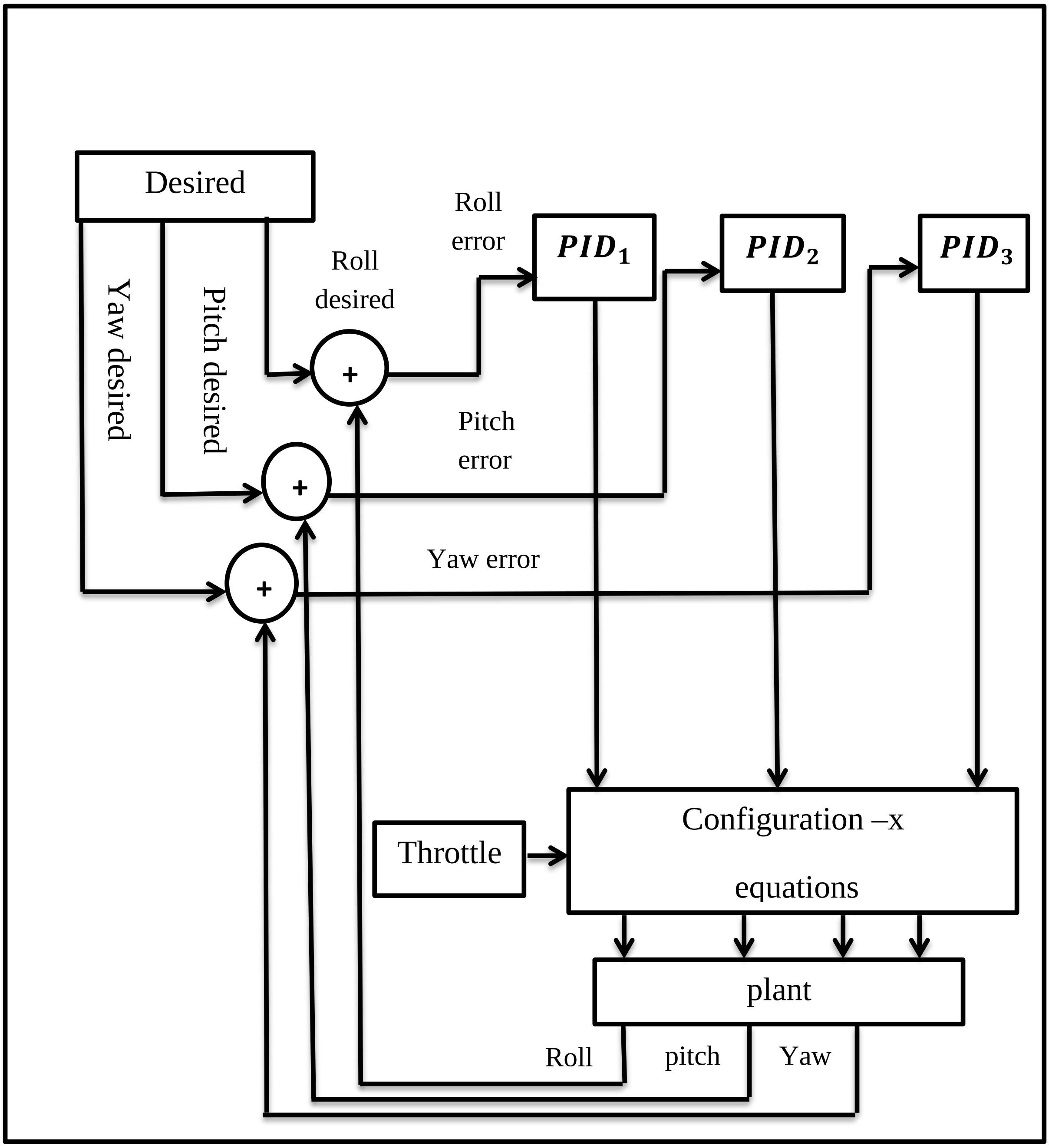


Figure (4) : Quadcopter system with three PID Controller

4- Object Detection Using Deep Learning Neural Network (D.N.N) Algorithm

The neural networks that have comparatively high depth are the deep neural networks (D.N.N.). it is a sub-class of neural networks. The idea of the deep networks is not recent but returns back to several previous decades. How to train the deep neural networks in practice, it is what is that we have figured out recently. The deep neural networks have become very common lately because their training has become feasible. The D.N.N are used by people to beat state of art algorithms. The D.N.N. require much of computational power and much of data which were not obtainable previously. Very promising results have been achieved lately by a deep learning in a large range of areas like: natural language processing, speech recognition and computer vision [9].

The deep learning algorithm relies on finding common points between the reference and the target image which is identified. The method of common points works best for objects that show non-recurring patterns and it is not likely to work well and appropriately with objects that have repetitive patterns or uniformly colored objects. D.N.N is used to detect a specific object such as faces, people, solids and others [10].

In the proposed system, the deep learning algorithm has been used to detect the intended target (sign (X)) for the automatic landing operation. The steps that have been taken during the Matlab program to detect the desired target(x) by the deep learning algorithm will be explained as follows:

1) Firstly, reading the reference image that contains the object from the local database and capturing a target image from the camera that is connected with a quadcopter and specifying the dimensions for both the images then convert the two images from (RGB) to gray scale image.

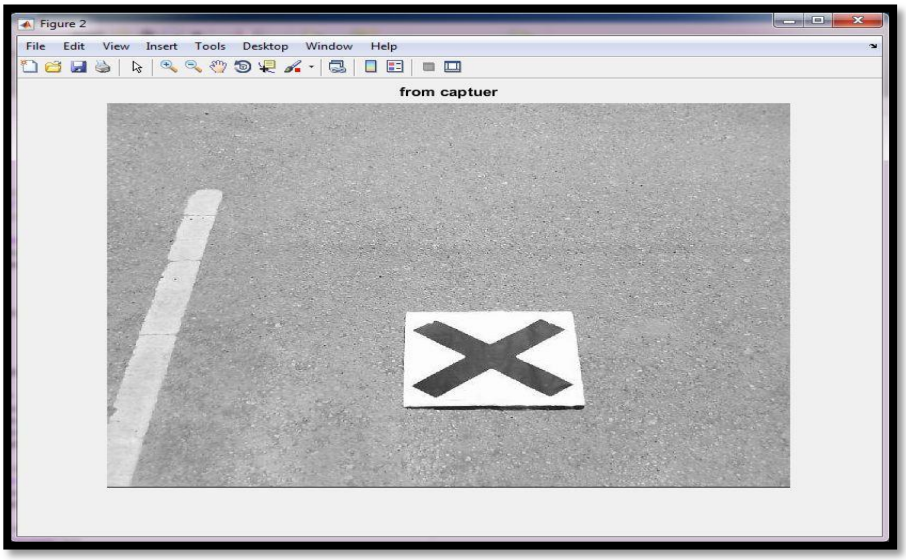


Figure (5) : Reading Target image and Reference image

2) Detect the feature points in both images (reference and target image), where visualize the strongest feature points which are found in the target image as seen with the green color. These feature points are represented by the bends that are centered at the edges and angles of both image as shown in figure (6a) & (6b).

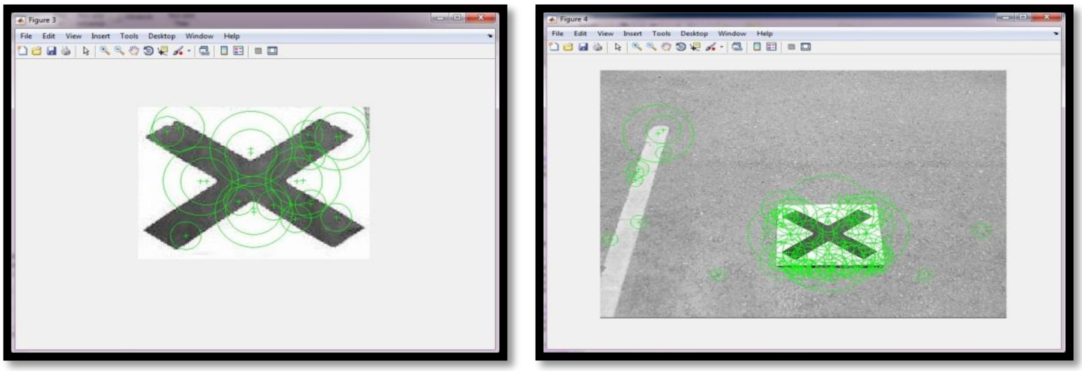


Figure (6a) Figure (6b)

Figure(5): Determination of strongest feature points in Target image

3) The two images are compared and searching for the common points between them. If there one 15 common points at least between the reference image and the target image, this means that the two images are identical. As shown in the figure (7), it is clear the common points between the two images are frequent at the edges, angles and the middle of them.

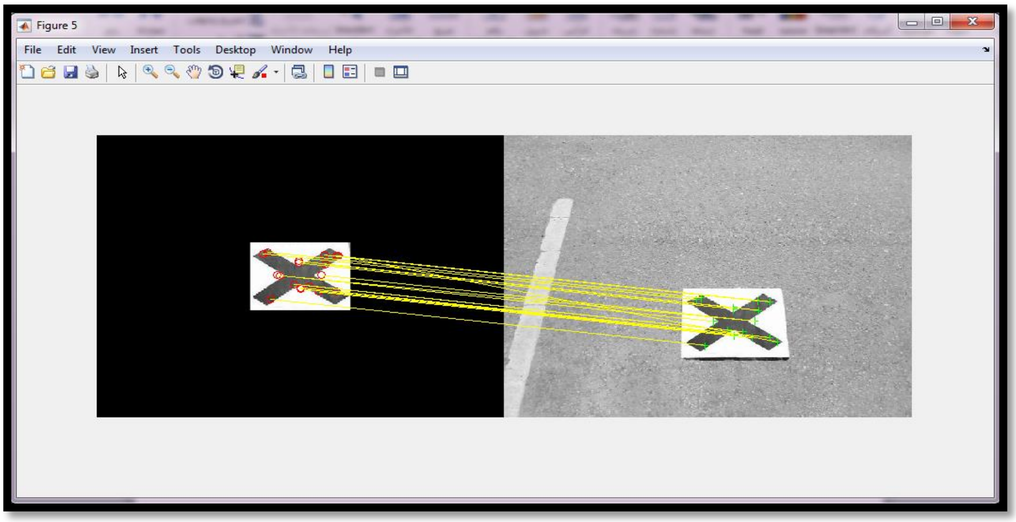


Figure (7) : Comparison and matching the points between the Target and Reference image

4) Detect the center of the desired target and also detect the center of the location of the target in the image. You can see two points with red color which are represented the center point for both. Where, a rectangle around the most powerful area of the target image is selected. So that the target (x) is defined within a rectangle with a specific dimensions. After specifying the x mark, the midpoint of the whole image is selected (this mean the center of the whole original image is selected) as well as the midpoint for the target image (this mean the center of the (x) mark is selected) as shown in figure (8). Figure (9) shows the flowchart for detecting the desired target (mark X).

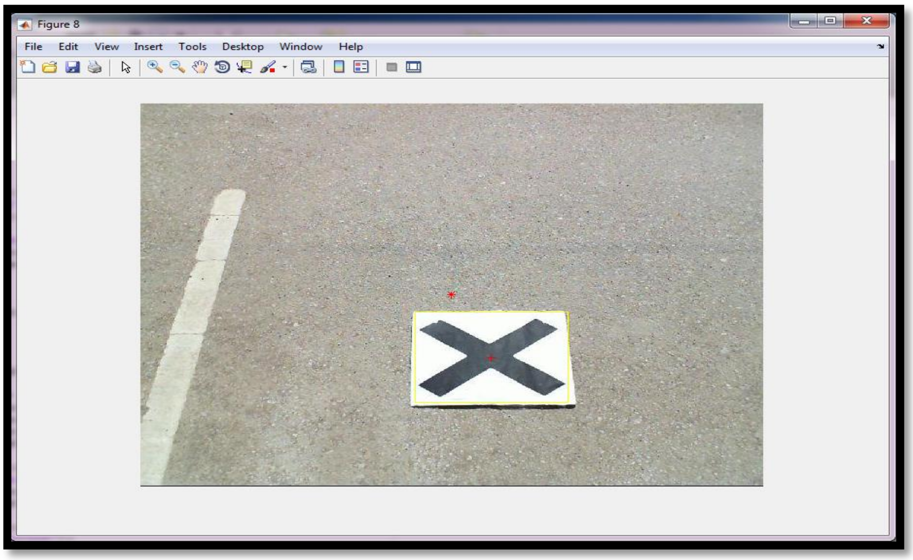


Figure (8) : Specify the desired Target within a Polygon Box

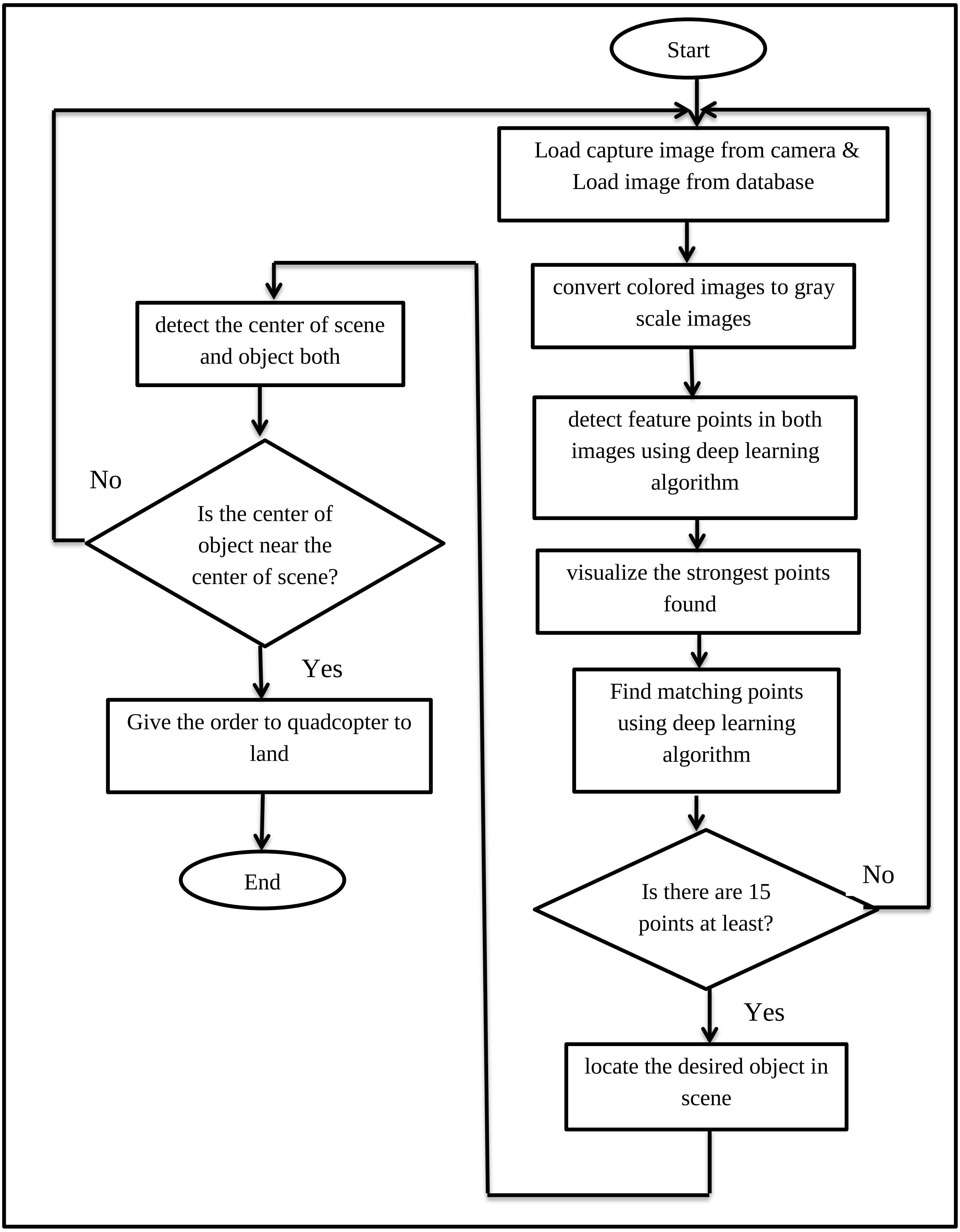


Figure (9): Flowchart of detecting the intended Target (x).

5- Circuit Diagram of the Proposed Quad-copter Designed

Figure (10) shows the proposed quad copter designed in this work.

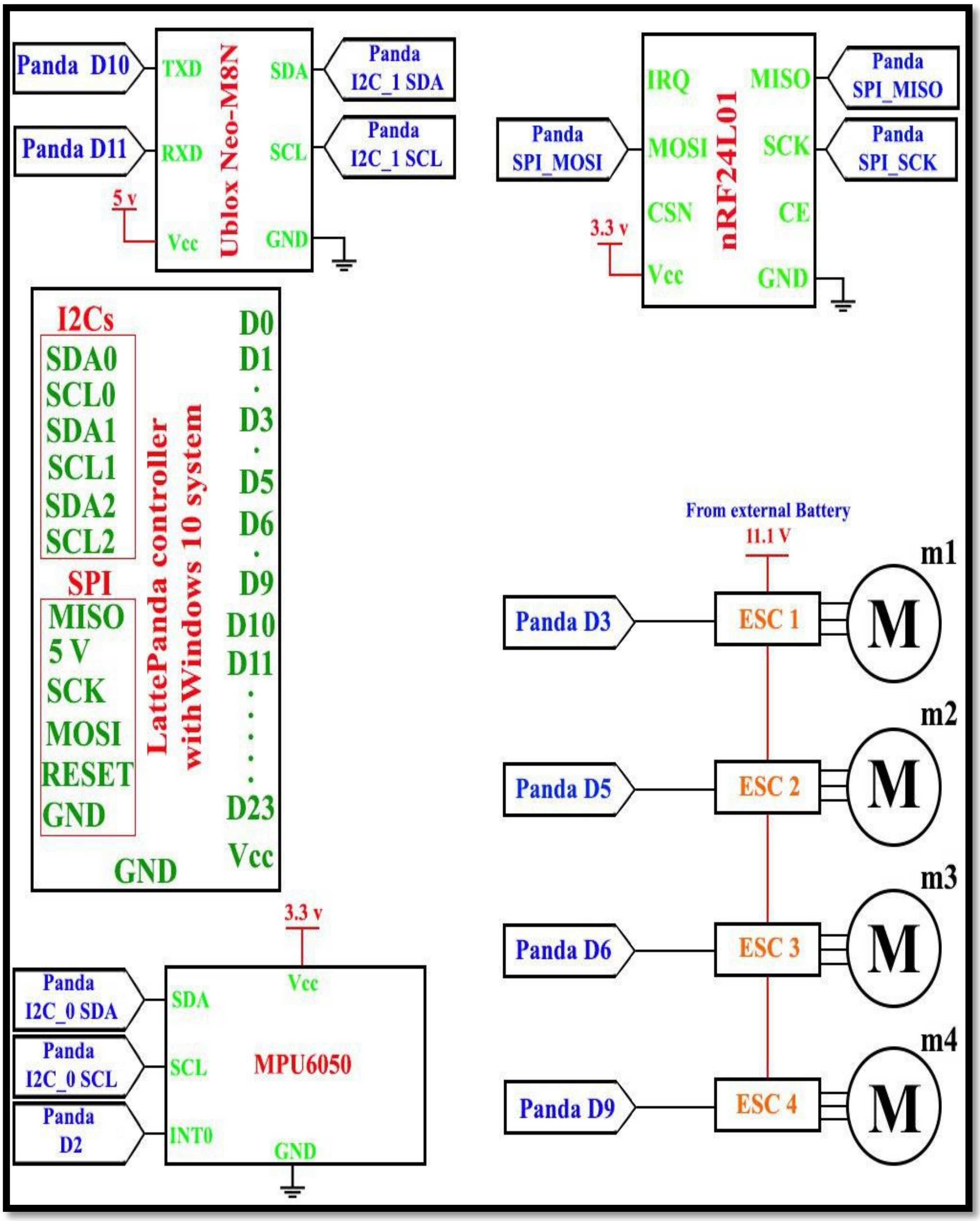


Figure (10) : Circuit diagram for the proposed quadcopter designed

6- Practical Results of the Desired Target (Mark x)

The procedure of the automatic flight operation and the process of detecting the required target are expounded in the following steps :

Step 1 : The quad copter begins to flight and searching operation for the desired goal (x) as shown in figure (11) .

Figure (11): Searching for the Desired Target (Mark X)

Step 2: The GPS determines both latitude and longitude for the location of the quad copter. Therefore, the target area of the landing was determined and the desired target is observed (X) as shown in Figure (12).

Figure (12): Determination the Intended Target (Mark X)

Step 3: A comparison between the goal image and reference image was making to find the common points between them. by utilizing the deep learning algorithm through the matlab program which is installed in the lattepanda board. finally, we can see the automatic flight operation of a quad copter is successfully implemented and the desired target has been observatied as depicted in figure(13).

Figure (13): Monitored the Desired Target (Mark X)

7- Simulation Results

Results show the response signals for each of the three movements in addition to the throttle of the quad copter. On the other hand, results show a comparison between the PID controller with and without IWO algorithm . One can see when the PID controller is optimized with IWO algorithm a good results for the PID parameters and response signals will be obtained.

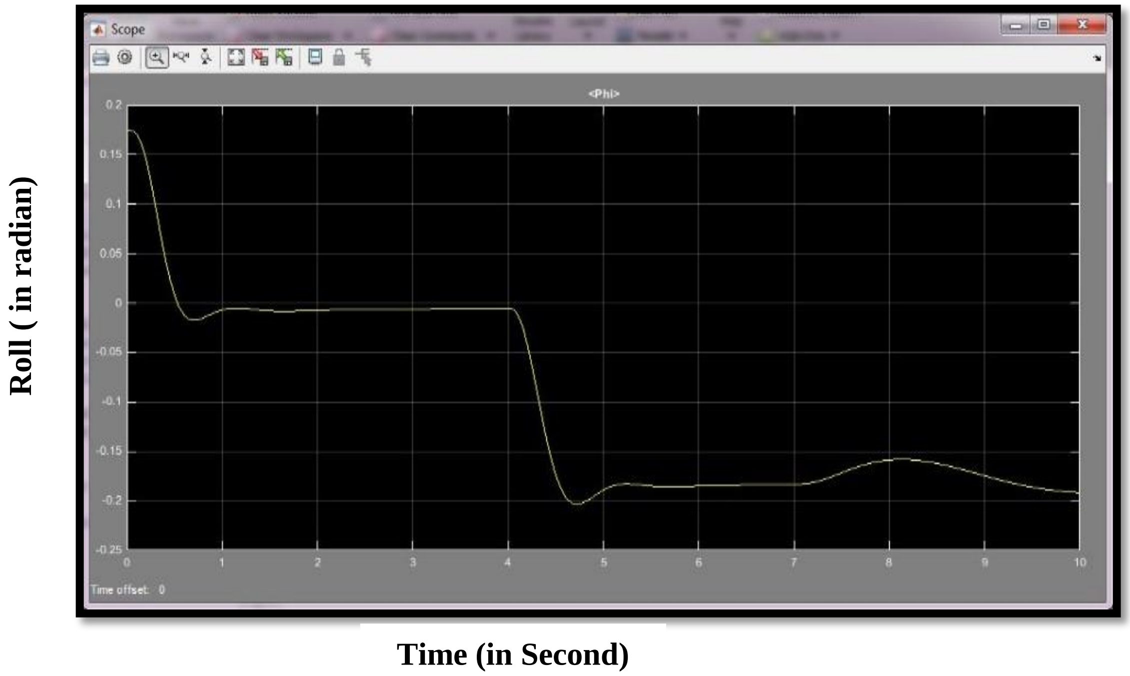
7.1 Roll Condition

Parameters of the PID controller for the roll motion for the control unit (PID) without and with optimized by (IWO) algorithm are given in table (1.1)

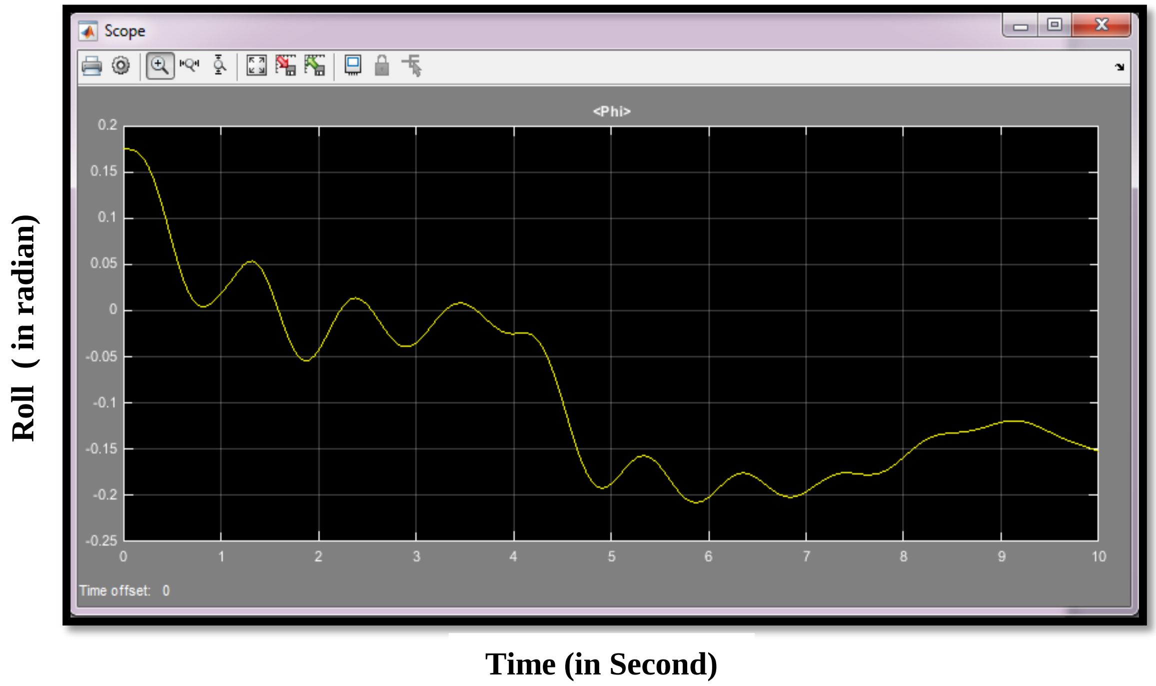
Table (1.1): PID Parameters for roll motion without and with (IWO) algorithm

PID Parameters	Values with (IWO) algorithm	Values without (IWO) algorithm
KP	4.256	3.256
KI	0.8986	0.6986
KD	2.0366	1.0366

Response signal for the roll motion for the control unit (PID) without and with optimized by the invasive weed optimization (IWO) algorithm are shown in figures (14 &15).



Figure(14) : Response signal of roll motion with (IWO) algorithm



Figure(15) : Response signal for roll motion without (IWO) algorithm

7.2 Pitch condition

Parameters of the PID controller for the pitch motion when the control unit (PID) without and with optimized by the invasive weed optimization (IWO) algorithm are given in table (1.2).

Table (1.2): PID Parameters for pitch motion without and with (IWO) algorithm

PID Parameters	Values with (IWO) algorithm	Values without (IWO) algorithm
KP	2.435	2.456
KI	0.4747	0.2986
KD	1.6877	0.466

Response signal for the pitch motion without and with the (IWO) algorithm are shown in figures (16 &17).

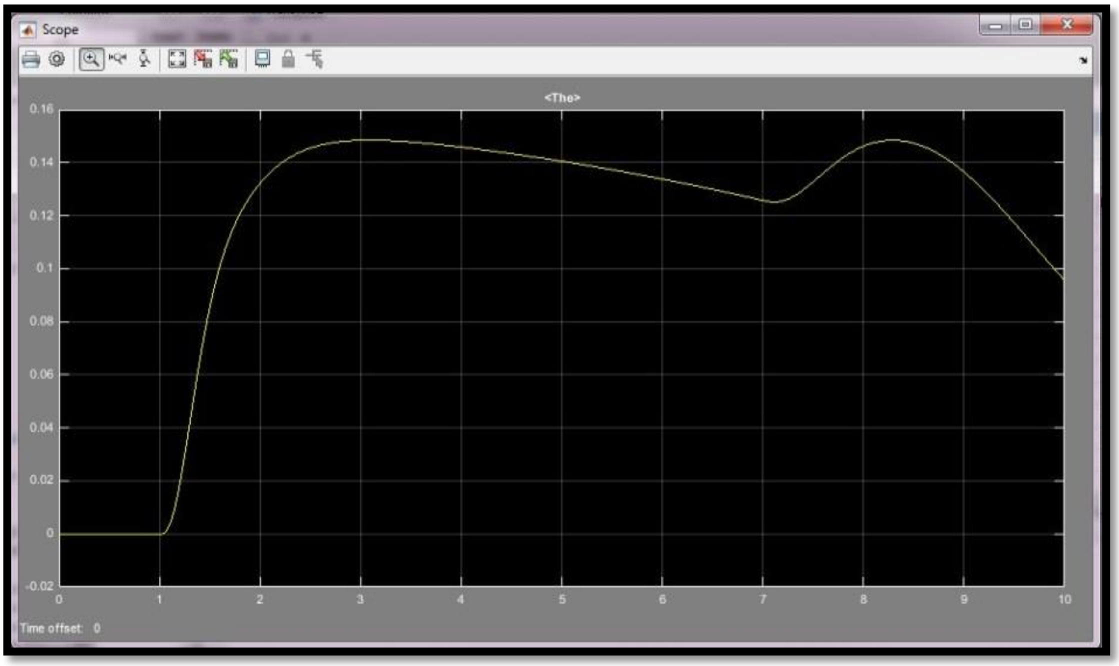
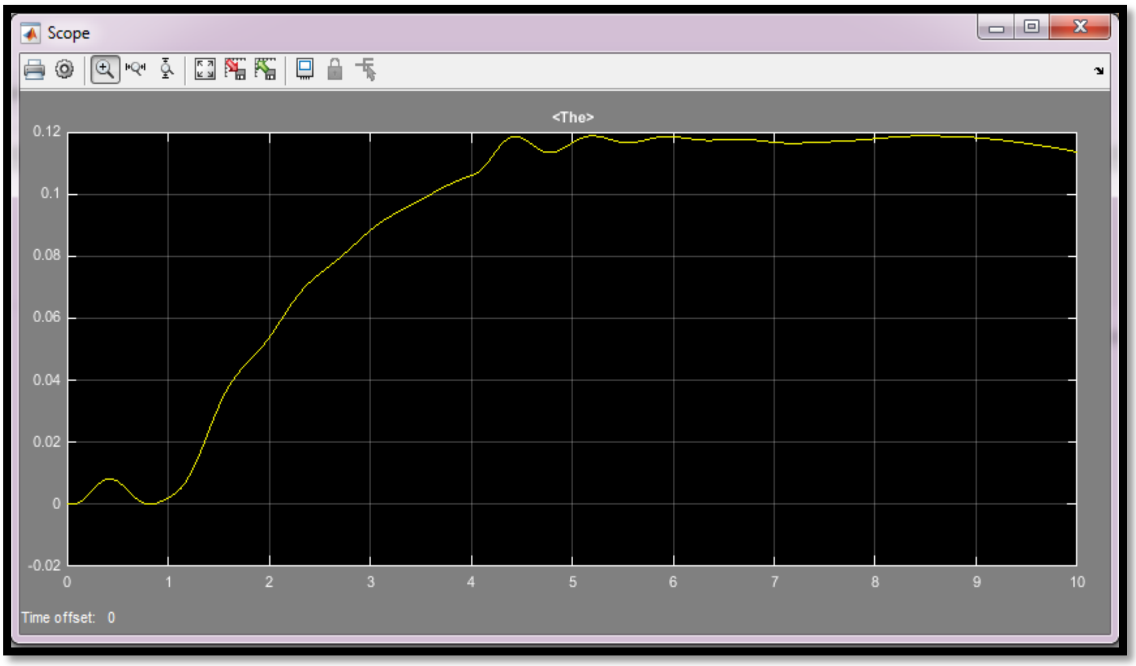


Figure (16) : Response signal for the pitch motion with (IWO) algorithm

Pitch (in radian)



Time (in second)

Figure (17) : Response signal for the pitch motion without (IWO) algorithm

7.3 Yaw condition

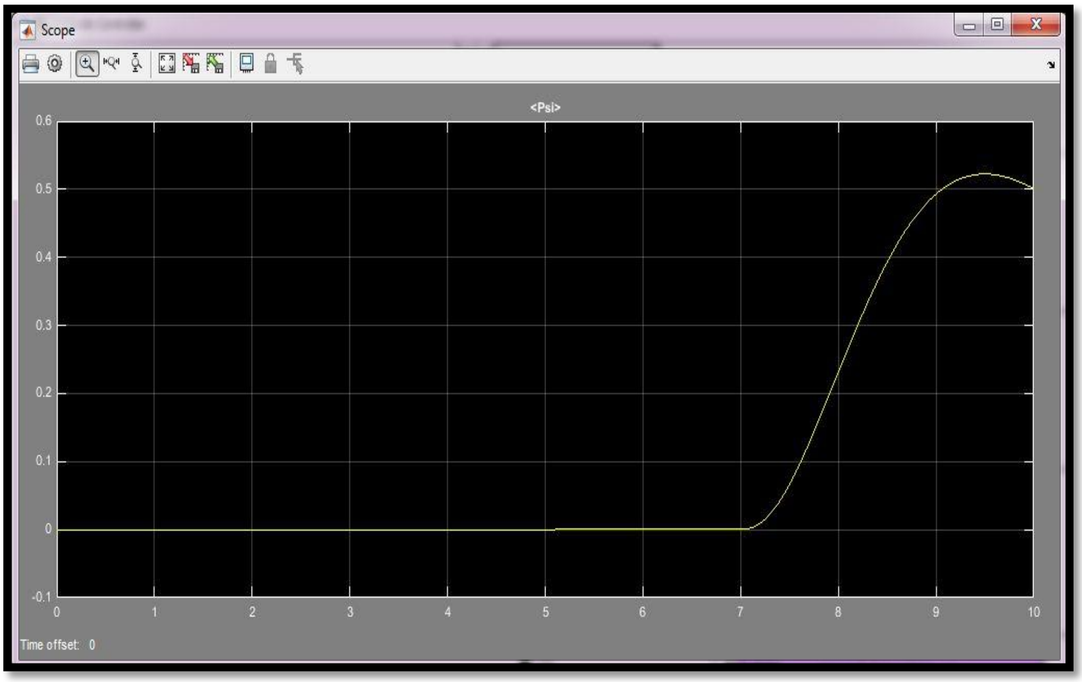
Parameters of the PID controller for the yaw motion when the control unit (PID) without and with optimized by the invasive weed optimization (IWO) are given in table (1.3).

Table (1.3): PID Parameters for yaw motion without and with (IWO) algorithm

PID Parameters	Values with (IWO) algorithm	Values without (IWO) algorithm
KP	2.8951	1.456
KI	0.988	1.2986
KD	1.982	0.778

Response signal for the yaw motion without and with optimized by the invasive weed optimization (IWO) algorithm are shown in figures (18 & 19).

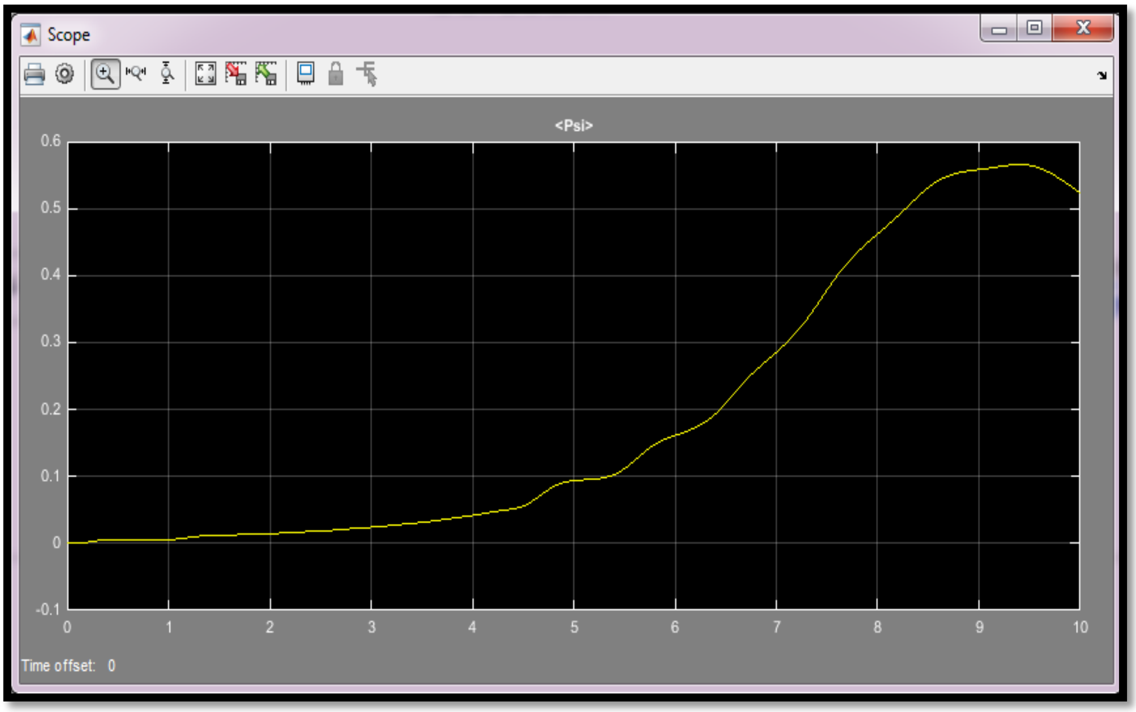
Yaw(in radian)



Time (in second)

Figure (18) : Response signal for yaw motion with (IWO) algorithm

Yaw(in radian)



Time (in second)

Figure (19) : Response signal for yaw motion without (IWO) algorithm

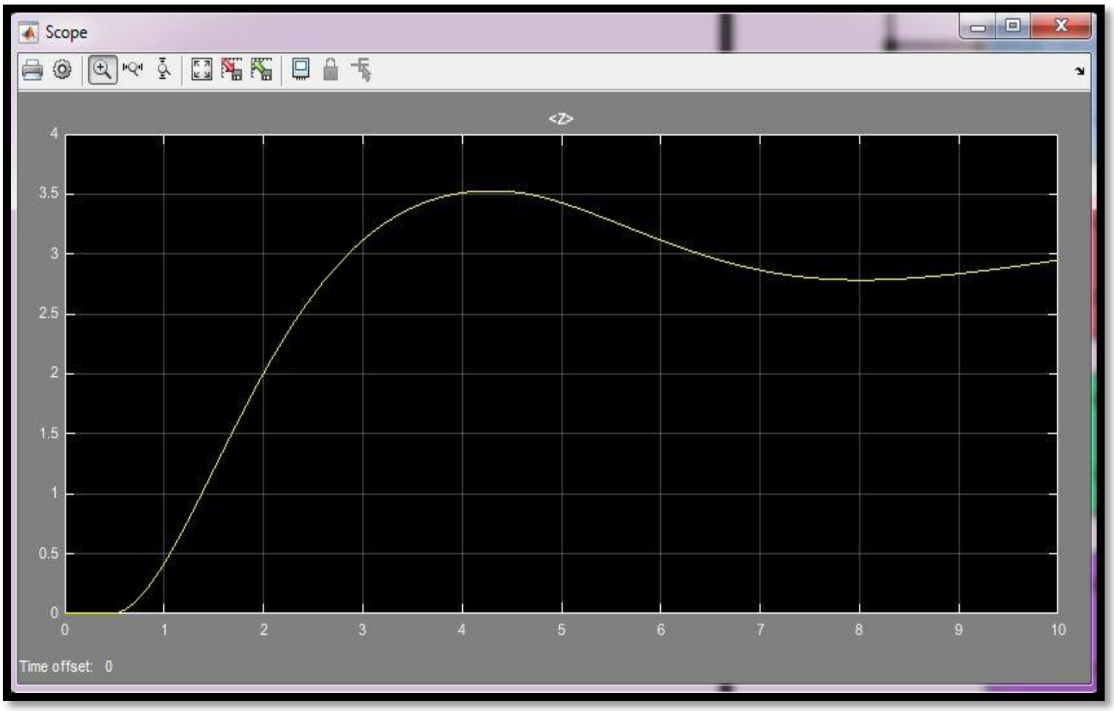
7.4 Throttle Condition

Parameters of the PID controller for the throttle of a quadcopter when the control unit (PID) without and with optimized by the invasive weed optimization (IWO) are given in table (1.4).

Table (1.4): PID Parameters for throttle without and with (IWO) algorithm

PID Parameters	Values with (IWO) algorithm	Values without (IWO) algorithm
KP	2.457	2.457
KI	1.203	1.203
KD	2.988	2.988

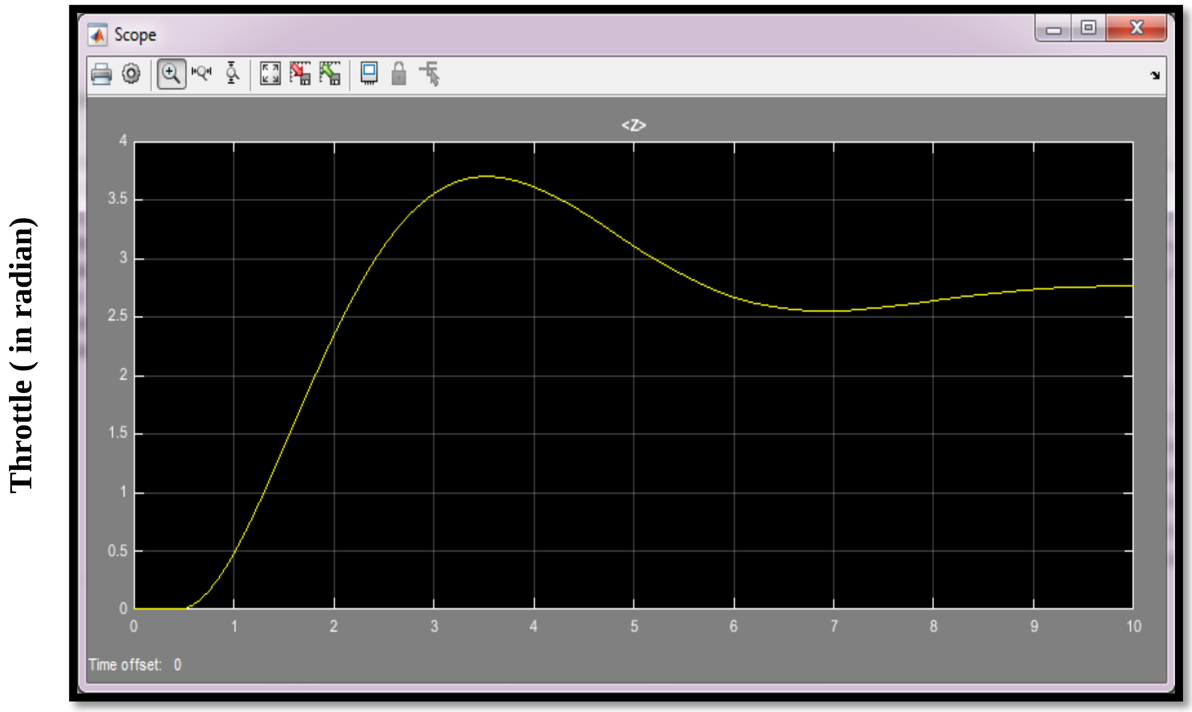
Response signals for the throttle of a quadcopter without and with optimized by the (IWO) algorithm are shown in figures (20 & 21).



Throttle (in radian)

Time (in second)

Figure (20): Response signal for throttle with (IWO) algorithm



Figure(21) : Response signal for throttle of quadcopter without (IWO) algorithm

8. Conclusions

In this work, the automated flight operation and the remote flight operation have been implemented with an advanced microcontroller board (lattepanda board) through the matlab program which is featured with fast and precise execution. In addition, the desired target (x) was detect by applying the deep learning algorithm (D.N.N).

The invasive weed optimization algorithm reduces the error values of the PID parameters for each of the three motion (roll, pitch ,yaw) and the altitude. On the other hand, the invasive weed optimization algorithm improves the response signal for each movements of the quad copter as you can see that from the comparison between the PID controller unit with and without the invasive weed optimization algorithm.

Also, from these results, it can be concluded that the PID controller achieves stability for each motion of the quad copter also it takes less time and needs a less memory through the implementation of the simulation system for the proposed quad copter.

9. References

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