

## **Quad-Copter Design and Fabrication by using Neural Network idea based on Advanced Microprocessor**

**تصميم وتصنيع طائرة رباعية بأستخدام الشبكة العصبية أستنادا الى معالج متقدم**

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**بحث مستل**

### **Abstract**

The current work aims to design and implement an independent quadcopter for locating a particular location and landing on a station of the required target. Where an outdoor quadcopter is designed and its flight is done by automatic flight. The quadcopter requires a wide control system for flight. Operation and tuning processes of the system become very difficult with existence of many parameters. Therefore, PID controller is optimized by the Invasive Weed Optimization (IWO) algorithm that is used to make quadcopter more stable, in addition to the sensors that help in achieving the stability and equilibrium for the quadcopter.

In the present work, movements of the quadcopter that are named as roll, pitch and yaw are controlled by three PID controllers designed for this purpose. Here, the LattePanda controller board, USB camera that is connected with the board of the quadcopter and Neo-M8N GPS are used to locate the target and monitor the (X) mark during the automated landing of the quadcopter. Matlab 2014b program is installed inside the microprocessor LattePanda which can detect the object (Mark X) by using Deep Learning Algorithm. The control unit (PID) was easy to implement the simulation system by using the Matlab 2014b and required a short execution time during the simulation.

**Key Words:** Quadcopter, Unmanned Aerial Vehicles (UAVs), Deep Learning Algorithm, autonomus quad-copter , Roll , Pitch , Yaw.

### **الخلاصة**

يهدف العمل الحالي الى تصميم وتنفيذ كوادكوبتر مستقلة لتحديد موقع معين وللهبوط على محطة الهدف المطلوب. حيث تم تصميم كوادكوبتر خارجي، يتم طيرانها أما عن طريق الطيران تلقائي أو عن طريق التحكم عن بعد. يتضمن التصميم على جميع الامور البرمجية والمادية والمسائل النظرية.

الكوادكوبتر تتطلب نظام مراقبة واسع للطيران حيث عمليات تشغيل وضبط النظام تصبح جدا معقدة مع وجود العديد من المكونات والمعاملات. لذلك تم استخدام وحده التحكم (PID) مع خوارزمية تحسين الأعشاب الضارة (IWO) التي تستخدم لجعل الكوادكوبتر اكثر استقرارا، بالإضافة الى أجهزة الاستشعار التي تساعد في تحقيق الاستقرار و التوازن للكوادكوبتر.

في العمل الحالي، حركات الطائرة التي تدعى: زاوية الخطران ( Roll ) و زاوية العطف (Pitch) و زاوية الأنعراج (Yaw) والأرتفاع (Throttle) يتم التحكم بها عن طريق اربع وحدات تحكم نوع (PID) مصممة لهذا الغرض، وكذلك يتم أستخدام لوحة التحكم (LattePanda) وللمرة الأولى في تصميم الكوادكوبتر و مايكروسوفت كاميرا (USB camera) على متن الكوادكوبتر ونظام تحديد المواقع (Neo-M8N GPS) لتحديد موقع الهدف ورصد الهدف المقصود (Mark X) خلال عملية الهبوط الالي للكوادكوبتر. خلال برنامج ماتلاب (Matlab 2014b) الذي تم تنصيبه داخل لوحة التحكم (LattePanda) ، يمكن تحديد كل من الهدف المقصود ، مركز الهدف والمركز المرجعي من خلال الكشف عن الكائن باستخدام خوارزمية التعلم العميق ( Deep Learning Algorithm)، وتعتمد هذه الخوارزمية على إيجاد نقاط مشتركة بين صورة الهدف التي تم تحديدها وصورة المرجع.

## **1. Introduction**

Quadcopters are the UAVs (unmanned air vehicles), through 20th century a first design of the quadcopter was introduced. The oldest known attempts have been made by the French World Etienne Oemichen in 1922. Quadcopters play a dominant role in many different fields such as fire sensing, military and civilian operations, surveillance and other applications that are involving more complexities [1].

As a result of their using with many applications and their wide importance in several fields, quadcopters popularity has been increasing with the systems of control and sensors. This has led to increase attention towards improving their capabilities and performance. This generally comes into two parts; the first part include the development of the hardware that is used in the design of the aircrafts while the second part includes the development of the control units and algorithms which are used in the control of the quadcopter system[2].

Through many applications, you can clearly see that the use of quadcopters in civil and military applications has become more popular and practical. For example, they are used in inspections in the oil and gas industries , inspection of transmission lines in the energy industry , mapping and facilitating the monitoring strategy[3].

The quadcopter has a small size as compared with other helicopters, therefore it prefers to use them in the indoor areas. It has a light weight and produces less kinetic due to the lower blades, which reduces the possibility of causing damage to surrounding things. In order for making the quadcopter able to fly in a stable state, there is must be an effective control system, this system consists of many parts, including gyroscope and accelerometers sensors and the control unit that produces the necessary control signals, that is usually executed with a microcontroller [4].

Quad-copters has been designed and implemented during many experiments, where G. Rodriguez with his group in 2012 [5] submitted method to detect and track objects from the unmanned aerial vehicles (UAVs) by using a single camera. M. Teach and his team in (2014) [6] offered fabrication and design of the quad-copter and V. Ingale with his group in (2015) [7] offered the controlling of quad-copter using android mobile devices (AMD).

In this work an independent quadcopter is designed and implemented for locating a particular location and landing on a station of the required target (Mark X) through the automatic flight. where, the USB camera on the board of the quadcopter, Neo-M8N GPS and the LattePanda controller board are used for the first time to locate the target and monitor (Mark X) during the automated landing of the quadcopter. By the object detection using the Deep Learning Algorithm, this algorithm relies on finding common points between the reference and the target image which is identified.

## **2. Equipments Need for the Design Proposed System**

### **2.1 Frame of the Quadcopter**

The quadcopter's frame is an important issue during a quad-copter's design. It's must be carefully considered in the design because it represents the main body of the quadcopter, which includes all the components that are used in the construction of a quadcopter. The aluminum is used with the current work because it's strong and light weight. The frame (x) has been used with the proposed work as shown in figure (1).



**Figure (1) : Frame (x) of Quadcopter Designed**

### **2.2 Propellers**

Two pairs of plastic propellers (10× 4.5) are used with the proposed work and the total length of these propellers is 254 mm. Two of these propellers spin clockwise and the other two spin counterclockwise as shown in figure (2).



**Figure (2) : Propellers of Quadcopter Designed**

### **2.3 Motor**

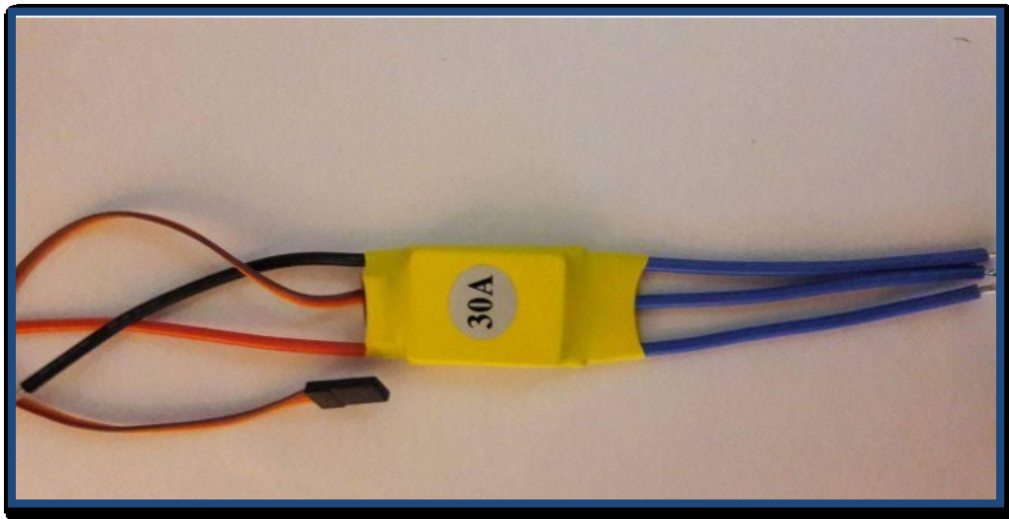
Here, high quality engines with quick response are need for control of the quadcopter. Therefore, four motors of brushless type are used with proposed system. The type of motors that used here is brushless motors A2212 / 6T with 2200kv. Figure (3) shows the brushless motor that is used in the quadcopter design [8].



**Figure (3):** Brushless Motor of Quadcopter Designed

### **2.4 Electronic Speed Control (ESC)**

ESC is an electronic circuit. It designed to drive the current into the motor. An electronic speed control with load current about 30A and light weight about 32g has been used with present design. Figure (4) shows the electronic speed control that is used with proposed quadcopter[9].



**Figure (4) :** Electronic Speed Control of Quadcopter Designed

### **2.5 Battery**

Lithium-Polymer (LiPo) battery has been used with current work. This battery consists of three cells, each cell has 3.7 volt and the total voltage for all cells is 11.1 volt. Figure (5) shows the battery that used in the proposed system with its track [10].



**Figure (5):** Lithium-Polymer (LiPo) Battery of Quadcopter Designed

## 2.6 LattePanda Controller Board

LattePanda is a single board computer with Windows 10 system as shown in figure(6). LattePanda has everything; where it can be easily handled in the installation and execution of programs. Also lattePanda is almost compatible with every device such as cameras, printers, joysticks and others. The panda controller is not only used as a computer, but it is designed with an Arduino-compatible co-processor. The lattePanda controller contains Arduino Leonardo just like the Arduino board. It is the heart of the quadcopter, that dominates the most operations like controlling the motors, electronic speed control and sensors, with the Arduino Leonardo that built into the LattePanda board[11].

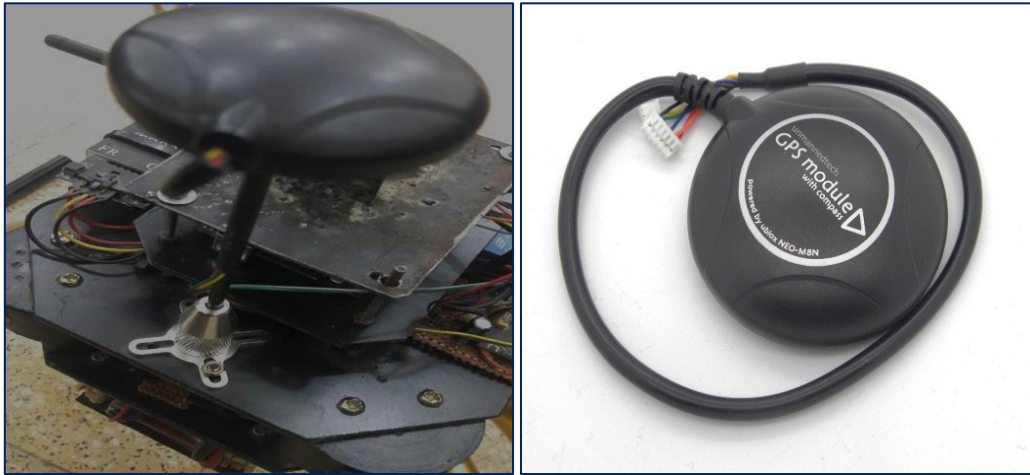
Due to the advantages of the lattePanda, it has been used with the present work for the automatic landing of the quadcopter. The voltage of Latte Panda is 5V and the current is 2A max.



**Figure (6) :** LattePanda Microprocessor of Quadcopter Designed.

### **2.7 Global Positioning System (GPS)**

The GPS module of type Ublox Neo-M8N has been used with proposed system. It contains a digital compass (HMC5883L) and has a high sensitivity. This module is surrounded by a piece of plastic to protect the GPS module of the rest of the elements as shown in figure (7). This type of Ublox Neo-8M GPS supports all satellite amplification systems [12].



**Figure (7) : Ublox Neo-M8N GPS of Quadcopter Designed**

### **2.8 Microsoft LifeCam Cinema Webcam**

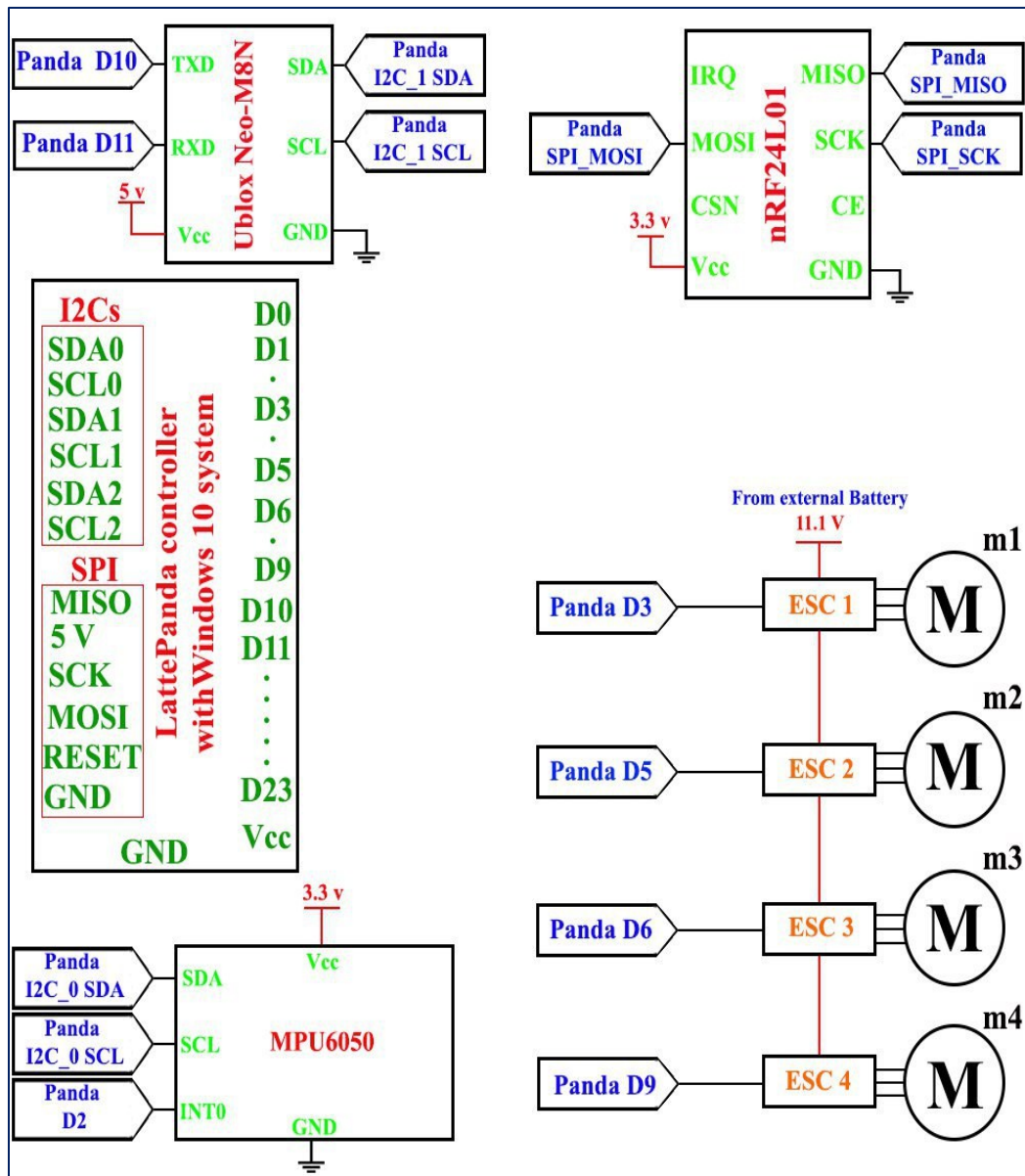
This webcam is built-in with high-quality glass lens. It can be autofocus 720p HD and uses the LifeCam cameras to enhance video in poorly lit environments. This type of camera is used because it is characterized by high-quality and high-clearly, where the quad-copter can see the target easily .The main objective of using this camera is the object detection by the quadcopter using the system adopted in the assignment of the image for the target. Figure (8) shows the LifeCam that is used with the proposed quadcopter.



**Figure (8) : Microsoft LifeCam of Quadcopter Designed**

**3. The Proposed Quadcopter Circuit Block Diagram**

Figure (9) depicts the connection diagrams of the circuits that are required for the design of the quadcopter.



**Figure (9) : Circuit Diagram for the Quad-copter Proposed Design**

**4. Automated Flight Operation**

In the proposed system, the autopilot is represented by the lattepanda board that is built in with arduino Leonardo.

When the input of the autopilot is determined, the copter will take off to the point that is designated through the GPS. Neo-M8N GPS locates the area containing the target but does not specify the point containing the exact target. When the quadcopter take off and starts looking for the intended target (which is represented in the current work as a sign (X)) by the microsoft camera, the lattepanda determines the points by the GPS until it reaches the specified point in the area concerned. Then, the camera is required to identify the target (sign (X)) and then the automatic

landing is completed. The main component of the quadcopter is the autopilot board which decides how much power is needed for each engine.

Deep learning algorithm is used to detect a specific object such as faces, people, solids and others. Programs that are used for image processing that developed in the automated quadcopter flight are implemented with the lattePanda controller for the first time is used to carry out the automatic landing of the quadcopter. In addition to a Microsoft LifeCam camera that is used to detect the landing spot and set the target on the land. Through the Matlab 2014b program that is installed inside the lattepanda, the target, target center and reference center are can be determined by the object detection using deep learning algorithm. In the proposed system, the deep learning algorithm is used to detect the sign (X) that has been specified as the intended target for automatic landing.

### **5. Simulation Results**

A PID mechanism is common in the industrial control system because of it is simple and direct method. The PID controller has a strong and exciting performance to get the best response for the parameters of the quadcopter. In this project the PID controller achieves stabilization by estimating the error for each of the roll, pitch, yaw and altitude z, and it is optimized with the (IWO) algorithm, for giving a better result of the parameters and improving the response signal for each of the four movements of the quadcopter.

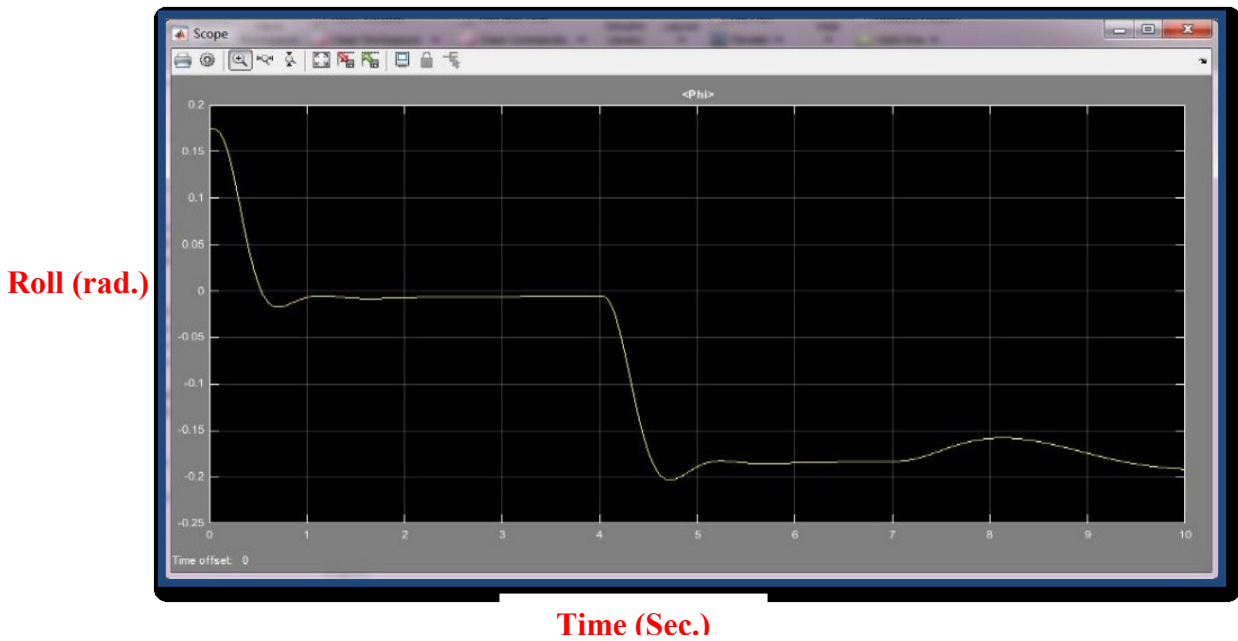
#### **5.1 Roll (Phi) Case**

The motion of the roll around the x-axis occurs when the right propeller's speed is decreased or increased with respect to the left propeller's speed. As a result of this procedure, the torque will be generated around the x-axis and making the quadcopter tilts around the x-axis causing the angle of roll. Parameters of the PID controller which are obtained from the simulation for the movement of roll are given in the table (1.1) and the response signal for the roll (Phi) movement is given in figure (10)

Table (1.1): Parameters of PID Controller for Roll Movement

Parameters	Value
Kp	3.168
Ki	0.5686
Kd	1.0368

The response signal for the roll movement is given in figure (10).



**Figure(10) : Response Signal for Roll (Phi) Movement**

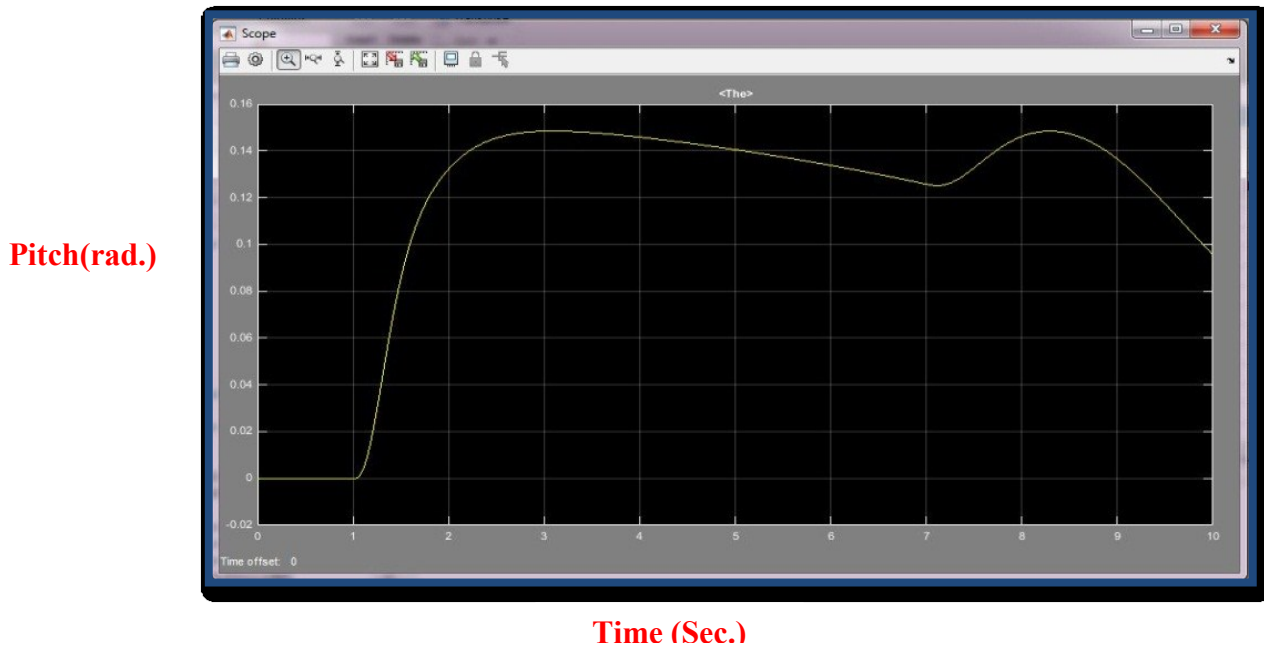
### 5.2 Pitch ( Theta) Case

The motion of the pitch around the y-axis occurs when the rear propeller's speed is decreased or increased with respect to the front propeller's speed. As a result of this procedure, the torque will be generated around the y- axis and making the quadcopter tilts around the y- axis causing the angle of pitch. Parameters of the PID controller which are obtained from the simulation for the movement of pitch are given in the table (1.2) and the response signal for the pitch (theta) movement is given in the figure (11).

**Table (1.2): Parameters of PID Controller for Pitch Movement**

Parameters	Value
Kp	1.8643
Ki	0.3747
Kd	1.2112

The response signal for the pitch (theta) movement is given in the figure (11).



**Figure (11) :** Response Signal for Pitch(Theta) Movement

### 5.3 Yaw(Psi) Case

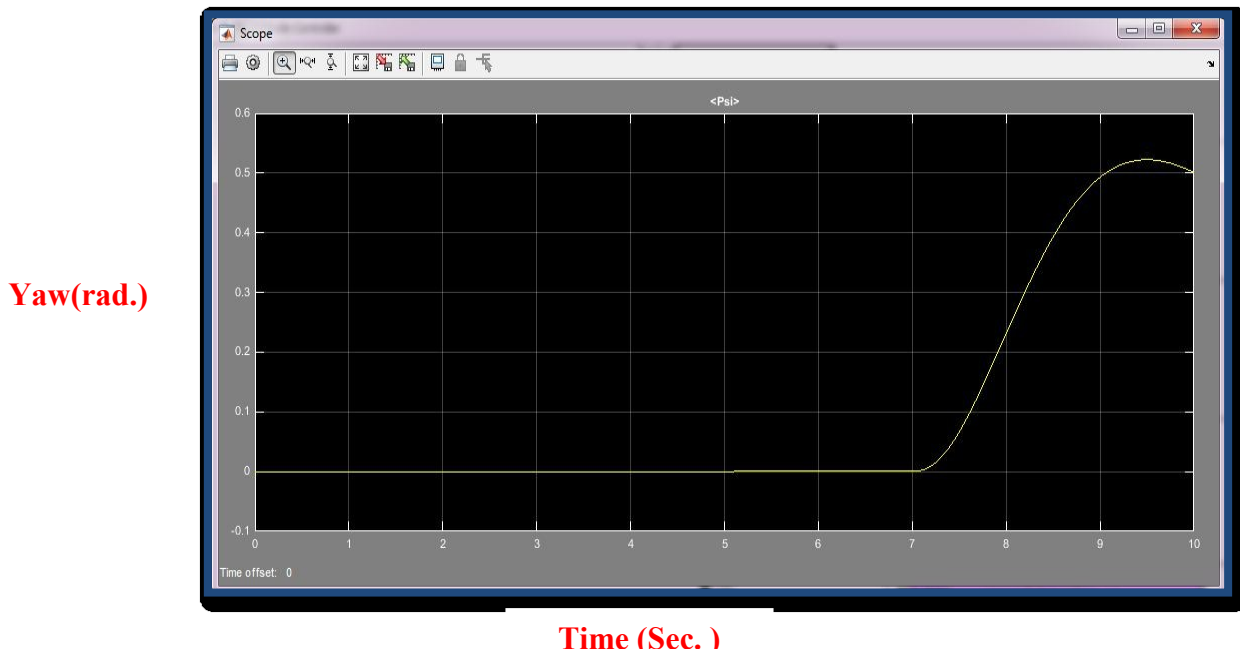
The motion of the yaw around the z-axis occurs when the speed of the rear propeller and the front propeller is reduced or increased accompanied by reduce or increase in speed of both the right propeller and the left propeller. This procedure generates an imbalance torque with regard to the z-axis so that the quadcopter becomes able to move around this axis to build-up the motion of yaw.

Parameters of the PID controller which are obtained from the simulation for the movement of yaw are given in the table (1.3) and the response signal for the yaw (Psi) is given in figure (12).

Table (1.3): Parameters of PID Controller for Yaw Movement

Parameters	Values
Kp	2.5121
Kd	1.1211
Ki	2.332

The response signal for the yaw (Psi) is given in figure (12).



**Figure (12) : Response Signal for Yaw(Psi) Movement**

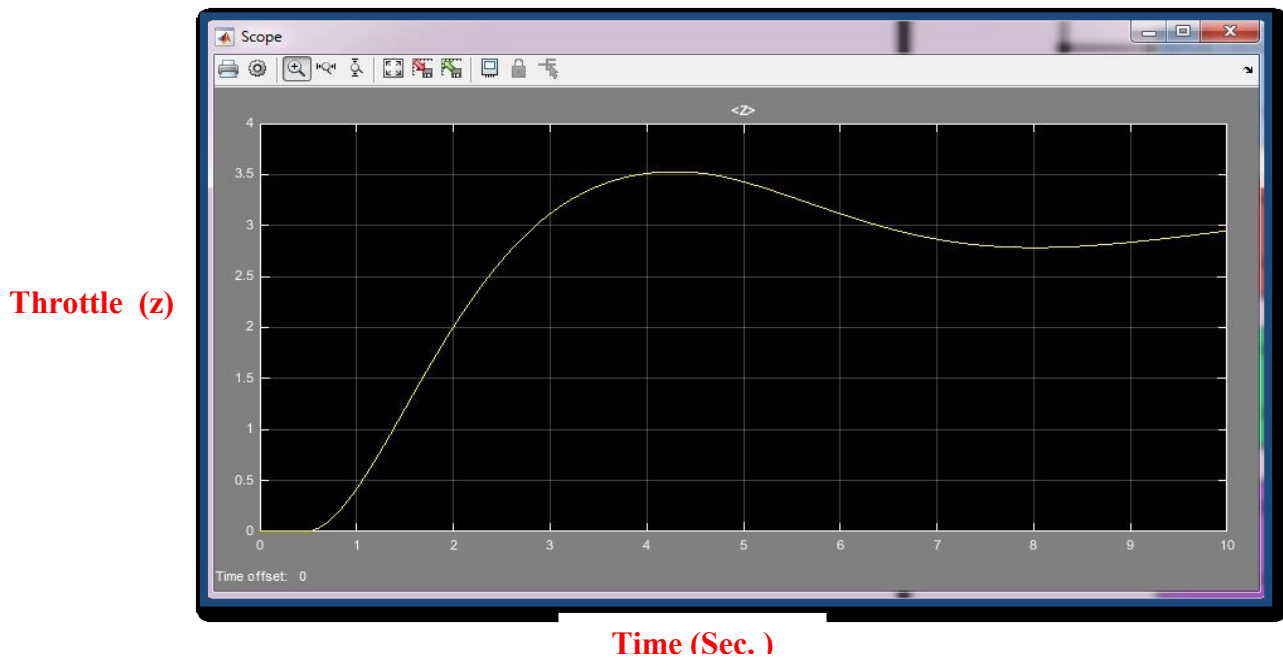
#### 5.4 Throttle Case

The response signal for the desired throttle ( $z$ ) is shown in figure (13). Parameters of the PID controller which are obtained from the simulation for the throttle are given in the table (1.4).

Table (1.4): Parameters of PID Controller for Throttle ( $z$ )

Parameters	Values
Kp	2.3929
Kd	1.0291
Ki	3.4042

The response signal for the throttle ( $z$ ) is shown in figure (13).



**Figure (13):** Response Signal for Throttle

### **6. Results of the proposed system with the Intended Target (x)**

The automated flight of the quad-copter and the determination of the desired target are explained in the following steps :

- First step: As shown in the figure (14), you can see the quadcopter which is installed on the ground, and it is equipped with all hardware and software for starting the process of automated flight.



**Figure (14):** The Design of Proposed Quadcopter System

- Second step: This step shows the starting of the automatic flight process which is achieved by the Lattepanda controller that is considered the brain of the quadcopter and as depicted in figure (15).



**Figure (15):** Automatic Flight of Quadcopter

• Third step: by using each of LattePanda controller board, USB Microsoft camera on the board of the quadcopter and Neo-M8N GPS, the quadcopter starts searching for the intended target (Mark X) as shown in the figure (16).



**Figure (16):** Searching for the Desired Target (Mark X)

• Fourth step: Each of latitude, longitude and altitude are specified by GPS for the position of the quadcopter, while the latitude, longitude and altitude of the position of the target are given to the Lattepanda microprocessor by the user. So, the intended area has been determined for landing and monitoring the desired target (Mark X) as depicted in figure (17).



**Figure (17):** Determination the Intended Target (Mark X)

- Fifth step: By using the Deep Learning Algorithm in the matlab 2014b that is installed in the Lattepanda microprocessor, you can make a comparison between the target image and reference image to find the common points between them. At the end you can see that the automatic flight process for the quadcopter has successfully occurred and the intended target has been monitored as show in the figure (18).



**Figure (18):** Monitored the Desired Target (Mark X)

## **7. Conclusions**

Here the quadcopter is designed and implemented successfully. Where, the test for the engines of the quadcopter is carried out to determine some important parameters to make the behavior of the quadcopter very good. Also Matlab2014b is used to control and simulate the mathematical model of it. It can be concluded from the results that the Matlab is very fast in simulating and controlling, very accurate and have excellent work with microprocessor Lattepanda. Stability has been achieved for each (roll, pitch and yaw) and the attitude of the quadcopter by using the PID controller that gives accurate results. In addition to, It can also concluded from the results that the PID controller needing less time for implementation and it is very simple also it need less memory storage.

In this work, a novel design is done by the use of Lattepanda as a controller board to achieve the automated flight of the quadcopter and monitoring the desired target (Mark X) by using USB camera. In addition to detect this target through applying the deep learning algorithm with Matlab 2014b.

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