Journal of Petroleum Research and Studies

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

DOI: http://doi.org/10.52716/jprs.v12i1(Suppl.).633

# Oil Facilities Surveillance Using an Autonomous Quadrotor

**Baqir Nasser Abdul- Samed**
Electrical Department, Oil Training Institute /Basrah
Corresponding Author E-mail: bakir_68@hotmail.com

6th Iraq Oil and Gas Conference, 29-30/11/2021



## Abstract

This work addresses using the autonomous quadrotor or unmanned aerial vehicle (UAV) for surveillance of oil fields, Facilities and pipelines since that can be very costly and dangerous specially in dangerous zones. This topic is very important because of the money consuming to repair and protect these oil facilities. Quadrotors are very small Vertical take-off landing (VTOL) helicopter, cheap, easy to use and has many other fields of applications. Quadrotor's dynamic model involves nonlinearity, uncertainties, and coupling which makes the Quadrotor has a very complex system. PID controllers are proposed for controlling the quadrotor altitude through different environments during different missions. To drive the quadrotor to follow the desired trajectory pure pursuit algorithm (PPA) will be use. The simulation results will be pretested using the visual simulator named Gazebo with the aid of ROS to connected with the MATLAB to show the movement of the quadrotor insides different environments.

**Keywords:** quadrotor, PID, PPA, GAZEBO, ROS, autonomous, oil field, pipeline.

## 1. Introduction

The quadrotor is a minor size helicopter and it is commonly used in many different applications. The first quadrotor was created in 1907 by Breguet-Richet Gyroplane. This quadrotor was manned and vertical takeoff and landing vehicle. Quick expansion in technologies and electronic circuits makes the quadrotor growth very fast to become unmanned aerial vehicle (UAV) and even smaller with minor cost and simple to use in numerous applications around the world [1]. Mostly, there are two configurations are used for the construction of the quadrotor: the cross-shape configuration or "X "and the plus shape configuration or "+ ". Each configuration has different features and application to be chosen as shown in Figure (1) [1]. In oil production pipelines and oil

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

fields performance an essential role in the oil industry that is because they consider the faster way to deliver and transport the crude oil or the refined products. Mostly the main oil products travel across the nation to reach the storage oil farms or refineries using the huge networks of pipelines.

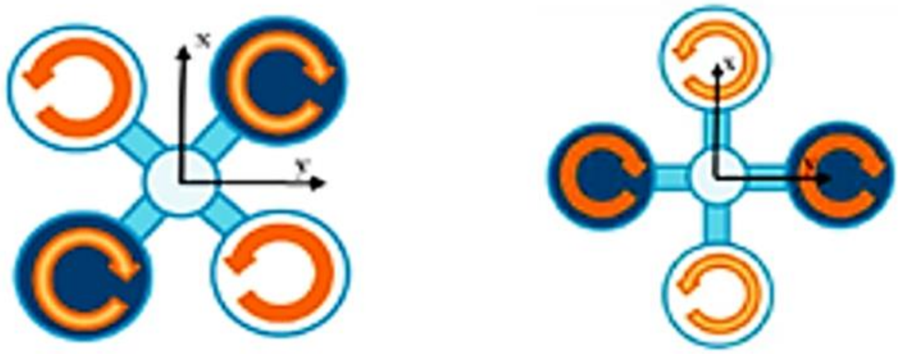

**Fig. (1): Configuration shape of quadrotor**

Millions of us Dollars are spending each year to protect the oil facilities specially in the hot zones where the wars still consuming the nations resources [2]. The arrangement of administrative control and data-acquisition (SCADA) systems has made it probable to monitor in real time the flow rate, pressure, and temperature of crude oil as it transfers from one facility to another. If for any reason the pressure is dropped somewhere in the pipelines network, the system can detect and arranged to report the human power automatically in that section and the operator will responded [3]. The operator immediately sends the quadrotor and drive it to specific location where the pressure is dropped, the quadrotor will deliver a video about the status of the pipelines as it moves.

Because of the wide using of the quadrotor in many fields civilian, military, weather, aiding and oil industry, this study focuses on using the autonomous quadrotor to surveillance the oil fields and pipelines. The last decades viewed wide activity of using the quadrotor in oil industry, it can be listed below [3]:

- Remote monitoring and surveillance.
- Inspection and predictive maintenance.
- Supplies assistance at risk areas.
- Methane management.

Open Access
No. 34 part 2, April 2022, pp. 211-224
P- ISSN: 2220-5381
E- ISSN: 2710-1096

- Emergency response.
- Material handling.
- Leak detection.

## 2. Literature Review

One of the most quadrotor's applications it can be used in several surveillance operations. As an example, the quadrotors are effectives to be used for monitoring the oil and gas pipeline [4]. Generally referred to the quadrotor as a UAV which is a hovering engine without man to drive. The quadrotor can be considered as another form of helicopter but with four identical rotors, the quadrotors applications recently can be found almost in all fields of life today [5]. In the oil and gas industry, the quadrotor has played an important role specially where the safety becomes the first priority. It is very useful for the oil and gas industry to save money by using a minor unmanned aircraft to patrol the oilfields. Presently, the oil and gas industry activities toward the practice of quadrotors for aground pipeline and facility monitoring [6].

Different researches studies have been presented about how to improve the using of the quadrotor inside the oil facilities to minimize the human effort and money. For that purpose, a new strategy presented especially because of the development of the communication and instrumentation [7]. Earlier, some researchers have completed extensive studies in the advance of mobile remote sensing systems for observing oil and gas substructures. For example, Ejofodomi presented the possibility of using small mobile robots for primary discovery of ground oil leakage, a procedure defined as Ground Robotic Oil Spill Surveillance (GROSS) [8]. Also, Ramon et al. [9], established a mobile stand called 'Turtlebot' for detection gas leakages. The control of the mobile base and the review device was integrated with a Robot Operating System (ROS).

MGR is the Oil and gas leak sensing Mobile Ground Robots, it is very dynamic inside well-structured oil and gas refinery also at the storage facility but the challenge was when it comes to gaining access to pipeline routes that run through swamps and thick bushes. Quadrotor with detectors now present the solution, quadrotor can fly above the pipeline networks and scanned the wide area for diffident locations at different environments and can be used instead of MGR [10]. Kelvin used that concept and

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

explored why that new mobile remote sensing using quadrotor was satisfying to be used for monitoring the Trans-Alaskan Pipeline [11]. Quadrotor's aerodynamics enables it to be the best choice for those types of jobs because it can hover with a lower speed and it can be controlled exactly on the desired spot efficiently much better than the fixed wing UAV which is not possible to stay above the particular spot for long time, this idea presented by Omijeh et al [12].

## 3. Robotic Operating System (ROS) and Gazebo

The simulation for the quadrotor movements building using 3D Gazebo simulator to show the simulated world when quadrotor doing different missions. It should be some commands send from MATLAB to gazebo to adjust the quadrotor path to goal as well as some information should fed to the MATLAB about the current position of the quadrotor. This where the ROS should interfere, ROS responsible for sending commands from MATLAB to gazebo world through the publisher, also responsible from getting new information about quadrotor position by subscriber. As shown in Figure (2) [13].

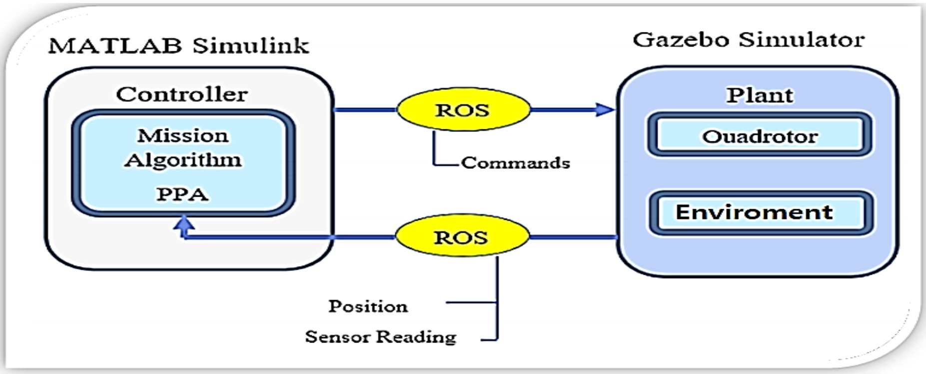


**Fig. (2): Simulink connected to Gazebo via**

## 4. Pure Pursuit Algorithm (Ppa)

PPA here to drive the quadrotor to follow a chosen path to complete its mission during a giving waypoint for single and multi-goals. PPA widely applied to achieve path following problem for the mobile robots. It is a geometrical technique based on finding the curvature that followed by the quadrotor to the chosen path point. The curvature that

Open Access
No. 34 part 2, April 2022, pp. 211-224
P- ISSN: 2220-5381
E- ISSN: 2710-1096

joins the current position of the quadrotor and the next point on the chosen trajectory is constructed (lookahead point). Fig. (3) shows the geometry of the pure pursuit algorithm. [14][15].

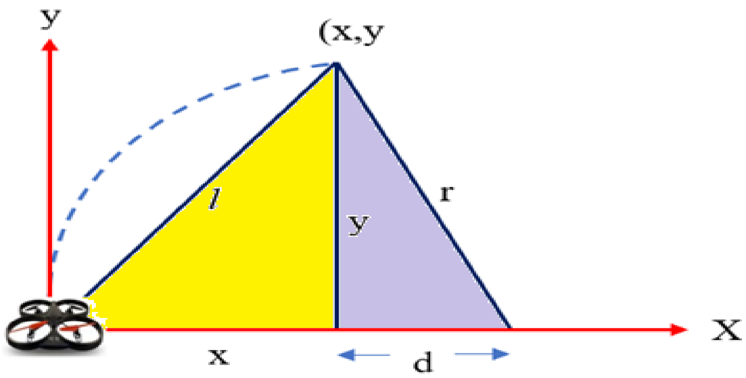


**Fig. (3): The geometry of the pure**

Figure (3) shows the point (0,0) is the current location of the quadrotor, while, the point (x, y) is the subsequent point (look-ahead) placed on the arc. The curvature of the arc joins the current point to the next point should be calculated. From Fig. (3) the following Equations can be written as:

$$x^2 + y^2 = l^2 \quad (1)$$

$$x + d = r \quad (2)$$

The equation (1) came from geometry of the left triangle in Figure (3). While the second from the summing of line segments on the x axis. In the Figure (3) the length of (x+d) on the X axis and r on the hypotenuse of right triangle seems not be the same. But actually, these are the same length r and constitute two sides of pie shape with arc[16]

Equation (2) can be rewritten as

$$d = r - x$$

from Fig, (3) the geometry of the right triangle can be written as:

$$d^2 + y^2 = r^2 \quad (3)$$

$$(r - x)^2 + y^2 = r^2$$

Simplifying the above equation yields:

$$r^2 - 2xr + x^2 + y^2 = r^2 \quad (4)$$

Now substitute equation (1) in (4)

$$r^2 - 2xr + l^2 = r^2$$

$$\Longrightarrow$$

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

$$l^2 = 2xr \qquad r = \frac{l^2}{2x} \tag{5}$$

So, the curvature (γ) can be calculated as

$$\gamma = \frac{2x}{l^2} \tag{6}$$

Equation (6) is just a relation between x offset of the goal point from the robot's coordinate and look-ahead distance *l*. Using equation (6); we can calculate curvature of the arc which joins robot's position and the look-ahead point. Equation (6) can be used to determine a proportional constant between linear velocity and angular velocity as following equation[16].

$$\omega = \gamma v \tag{7}$$

Where

ω is the angular velocity

γ is the curvature of the arc

$v$ is the linear velocity

To use the PPA in the simulation using MATLAB it should first generating waypoints from the start point to the goal point.PPA used to drive the quadrotor using the curvature calculated above from any point to look-ahead point arriving to the end. Figure (4) shows the PPA Simulink.

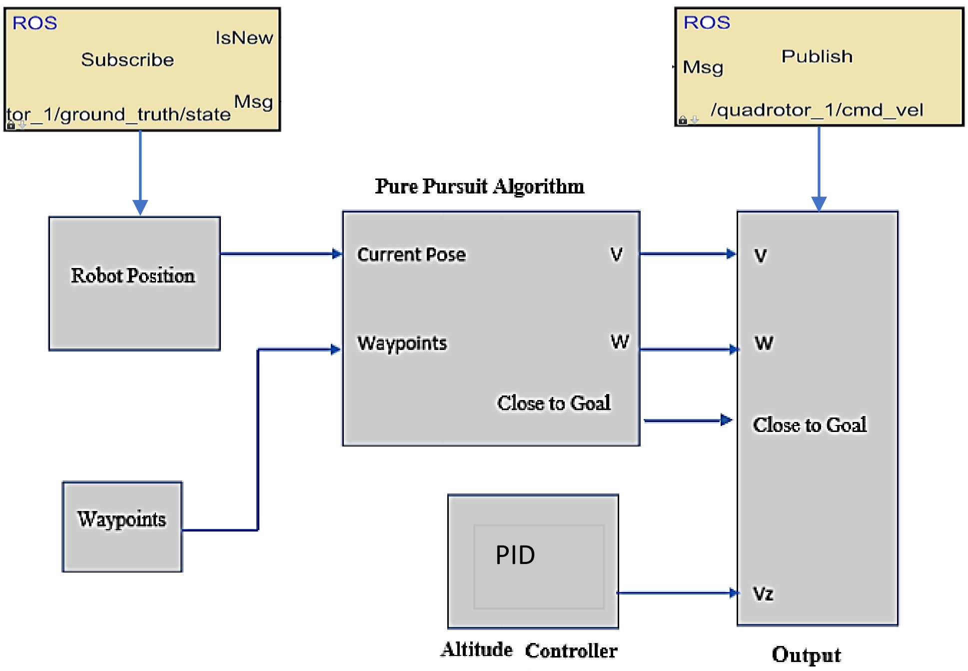


**Fig. (4): Pure Pursuit Algorithm**

Open Access
No. 34 part 2, April 2022, pp. 211-224
P- ISSN: 2220-5381
E- ISSN: 2710-1096

ROS subscriber used to receive the sensor readings from Gazebo concerning the quadrotor current position and fed them to PPA while the ROS publisher used to receive commands from PPA and send them to the Gazebo to update the quadrotor position.

## 5. Simulation and Results

The navigation problem in this work is introduced to the quadrotor. The quadrotor supplied with two attached cameras one for the front view and the other for the bottom view for visualization purpose.PPA for path planning to drive the quadrotor in order to follow waypoints along the desired path. The Gazebo simulator is used to show the 3D view of the flying of the quadrotor with the aiding of ROS. For checking the success of the PPA algorithms two different situations are considered as shown below:

### 5.1 Pipe Line Simulation

In this scenario, the quadrotor will fly above the pipelines using the PPA algorithm; the pipeline environment designed using 3D gazebo. Figures (5) to (10) shows the pipeline environment.

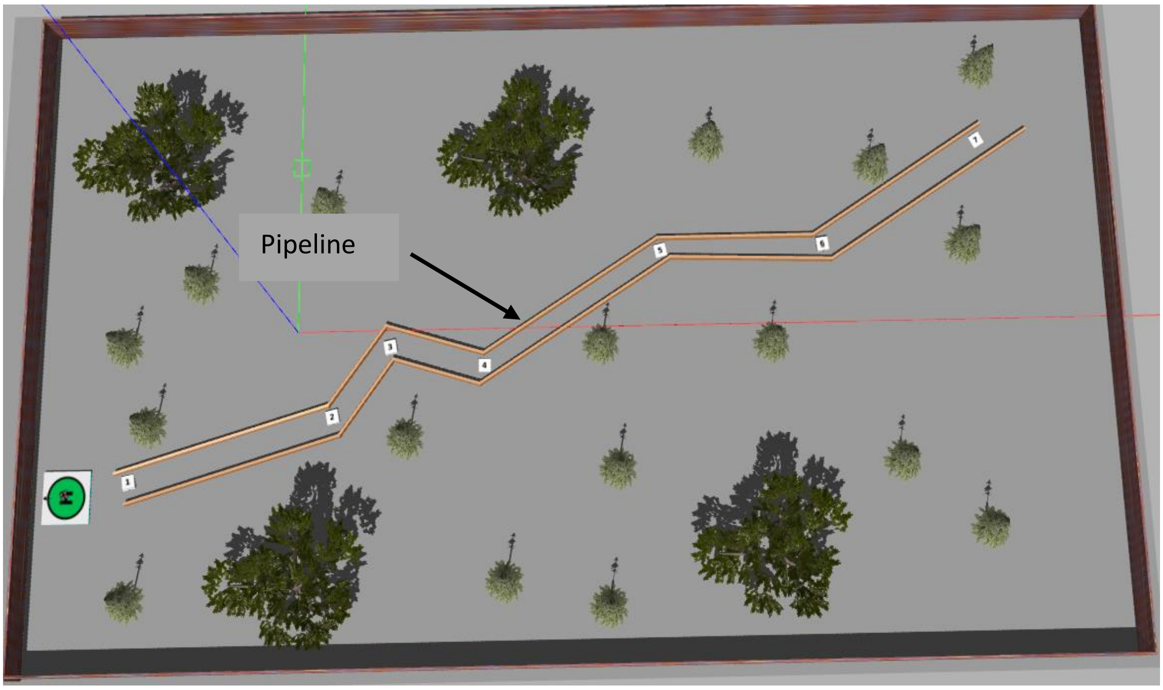


**Fig. (5): Pipeline environment**

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

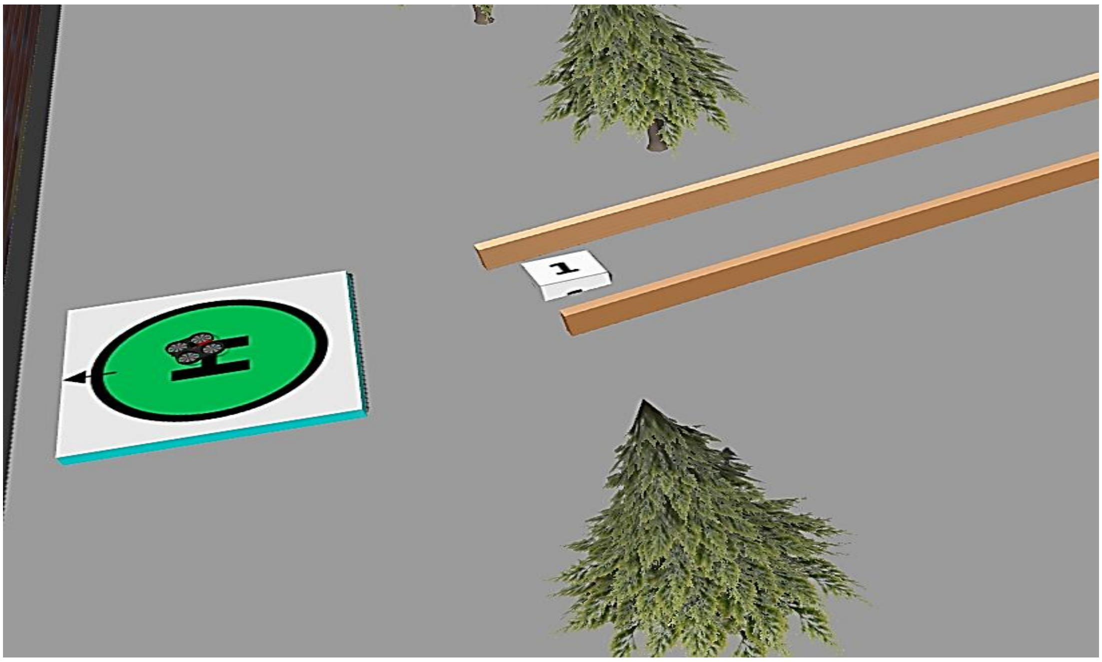

Fig. (6): Quadrotor at start

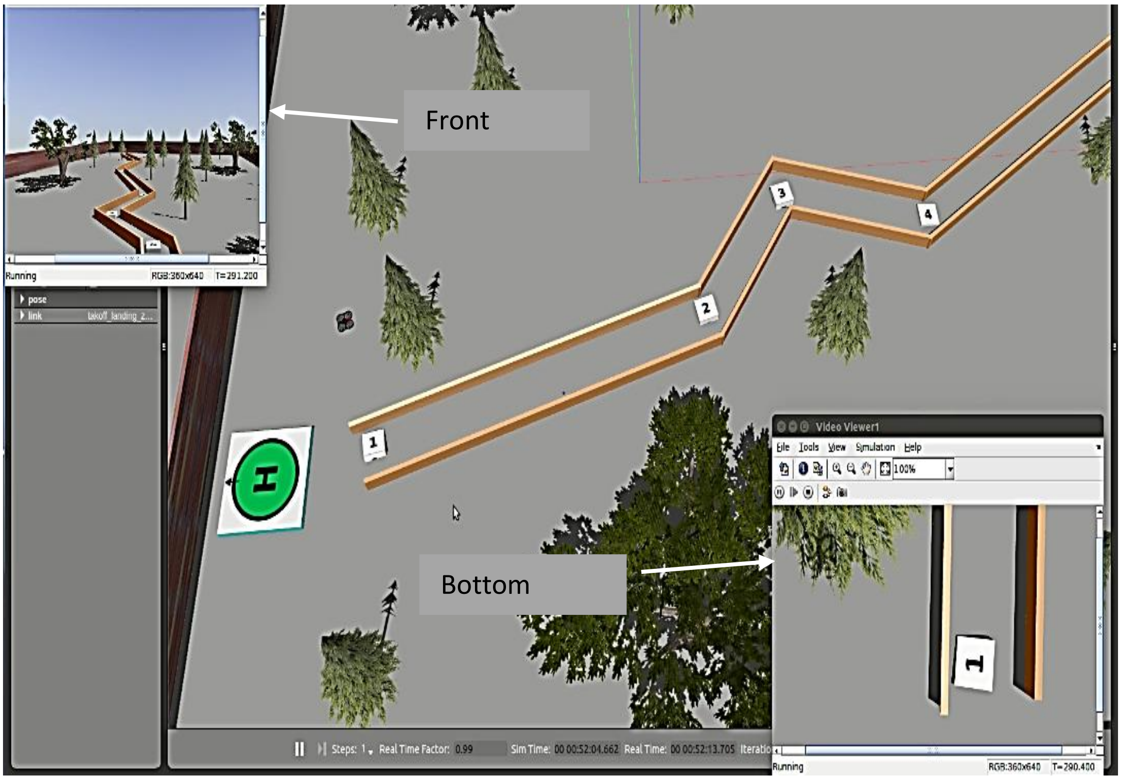


Fig. (7): Quadrotor at first point

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

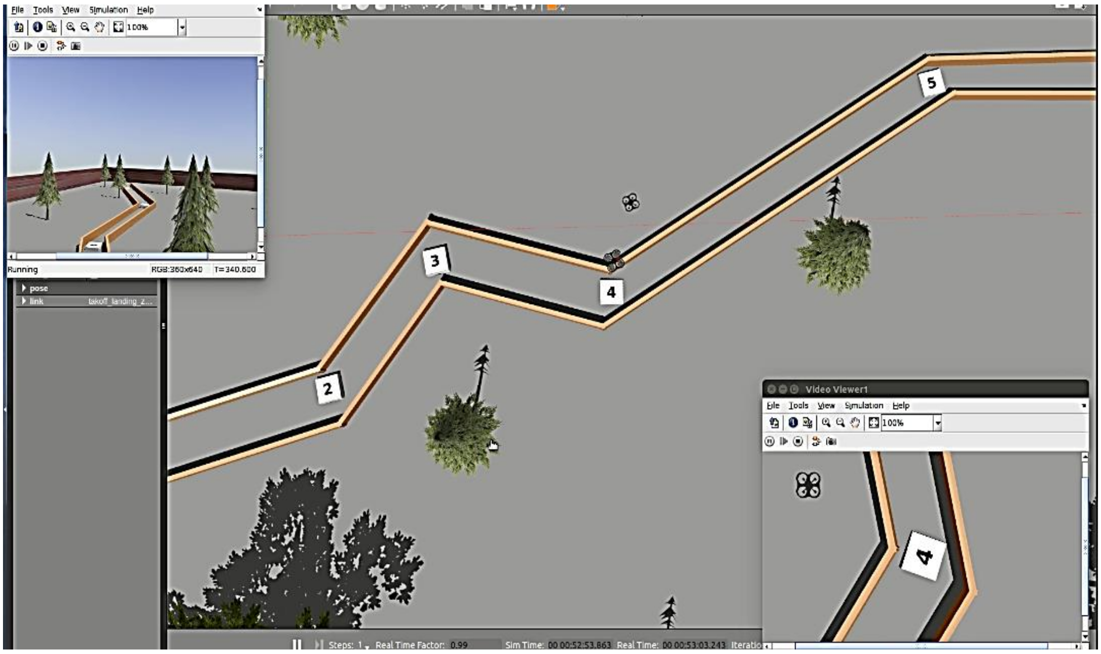

Fig. (8): Quadrotor at fourth point

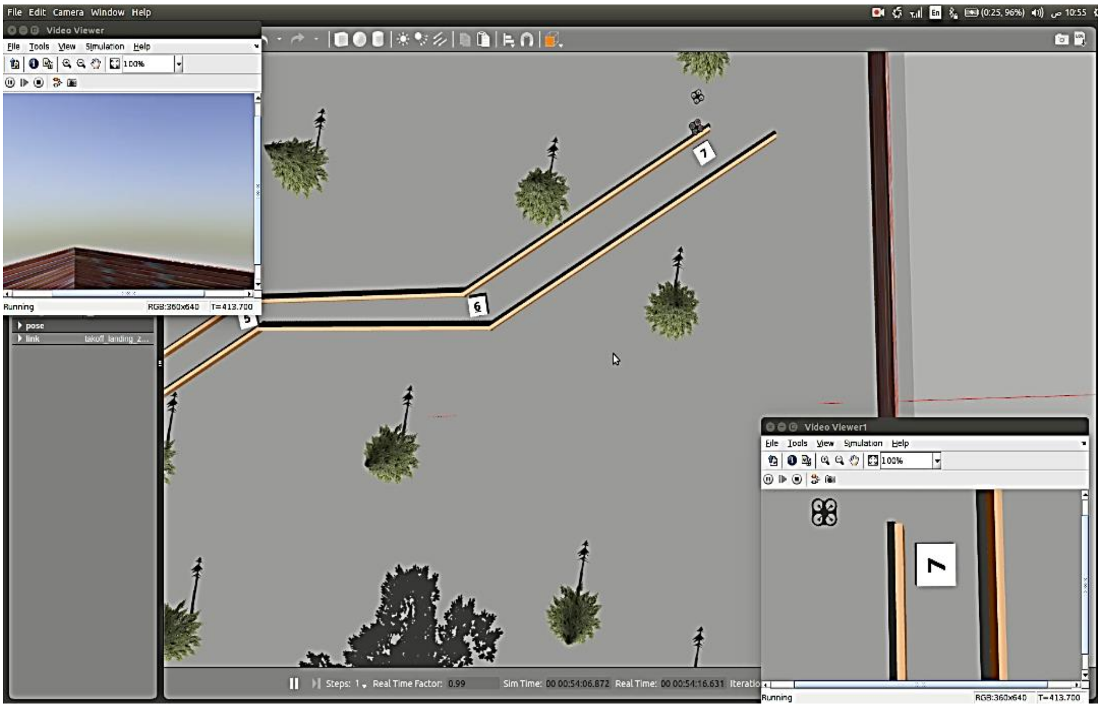

Fig. (9): Quadrotor at last point

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

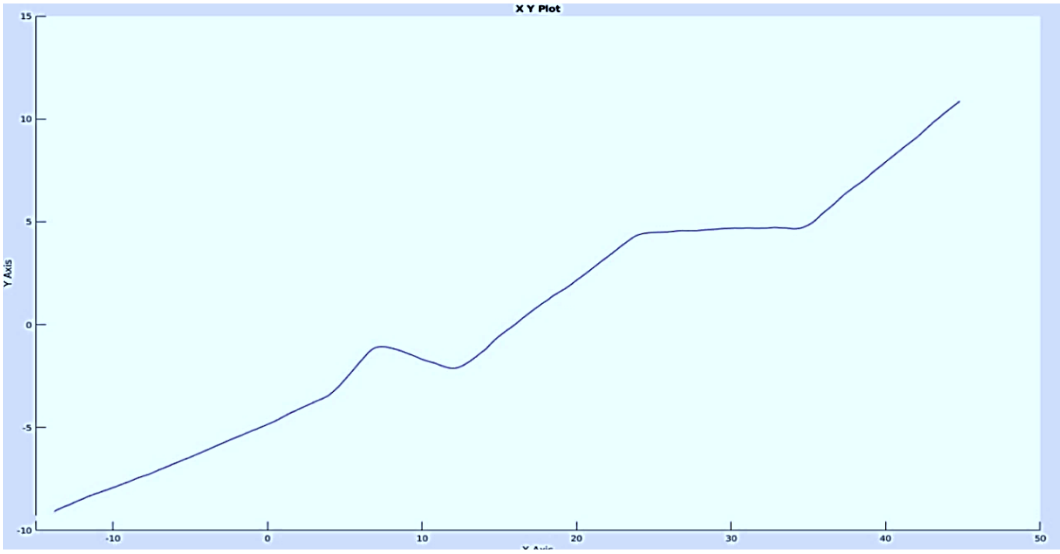


**Fig. (10): Quadrotor Path**

### 5.2 Oil Field Simulation

In this scenario, the quadrotor using the PPA will observe the oil field by flying around that oil facility to check if there is any leak, threat or any problem and it will forward that to the responsible person using the two cameras that attached to the quadrotor, the front and the bottom camera to respond. Figure (11) shows the oil field environment.

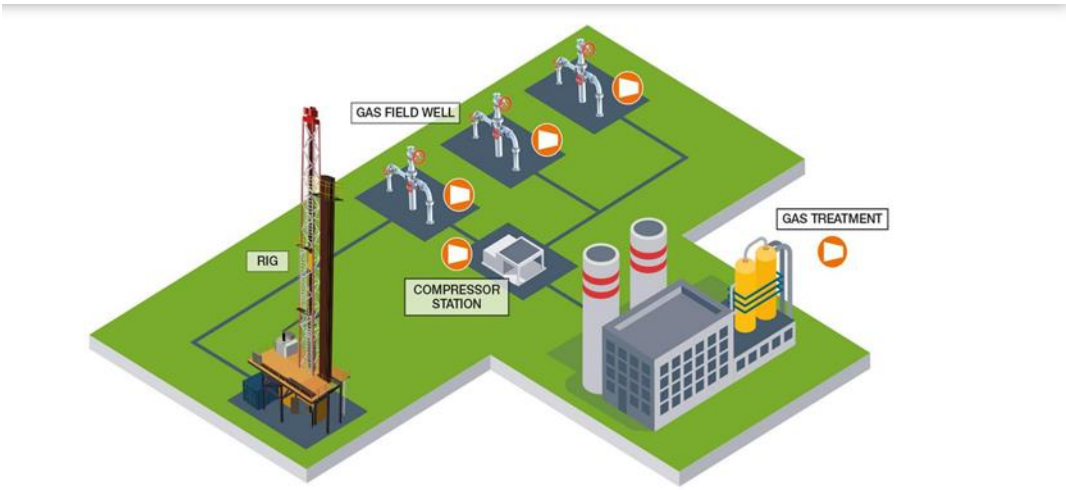


**Fig. (11): Oil field environment**

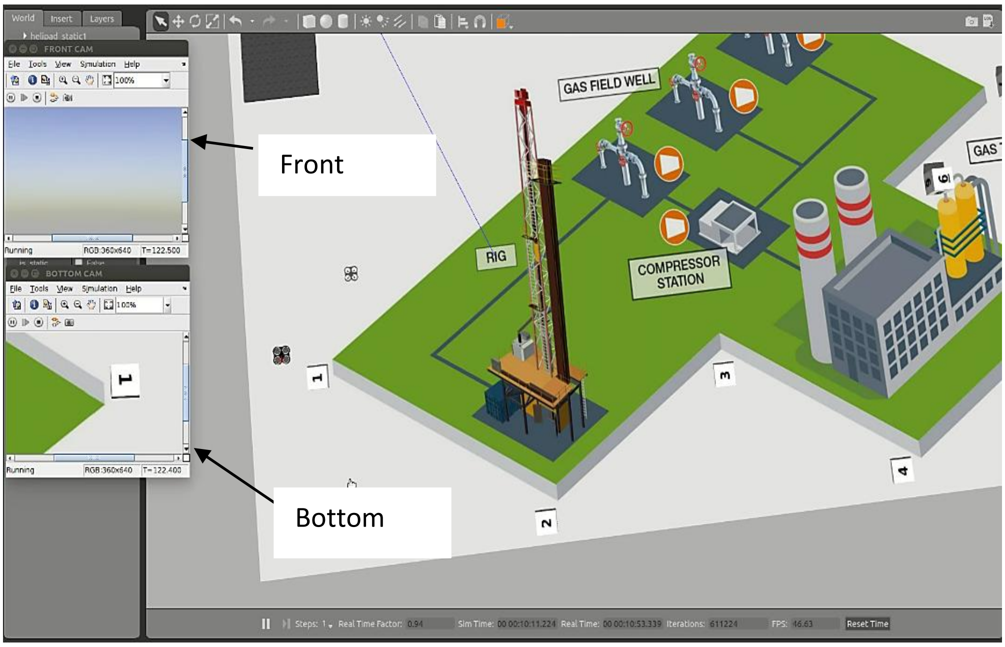


**Fig. (12): Quadrotor at first point**


**Fig. (13) Quadrotor at fourth point**

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096


**Fig. (14): Quadrotor at last point**

## 6. Conclusions

Quadrotor is widely used almost in all fields of life like military, civilian, firefighting and also in the oil industry. Because of the flexibility of using of the quadrotor, it has been suggested to protect the oil industry using the quadrotor for monitoring and surveillance purpose. In this work PPA algorithm was introduced to map the quadrotor between a start point and the goal point in the desired path, two scenarios have been suggested, and implemented using MATLAB with the aid of 3D gazebo simulator via ROS. The first one was quadrotor flying above pipelines for the surveillance purpose using waypoints and it was implemented successfully. The second one was a strategy of using a quadrotor to fly around the oilfield to check if there is any problem or threat to be respond immediately.PPA algorithm is used by force the quadrotor to follow a waypoint to guide the quadrotor to achieve the planned goals in different environments for different missions.

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

## References:

[1] S. Norouzi Ghazbi, Y. Aghli, M. Alimohammadi, and A. A. Akbari, “Quadrotors unmanned aerial vehicles: A review,” *Int. J. Smart Sens. Intell. Syst.*, vol. 9, no. 1, pp. 309–333, 2016, doi: 10.21307/ijssis-2017-872.

[2] F. E. Idachaba, “Monitoring of Oil and Gas Pipelines by Use of VTOL-Type Unmanned Aerial Vehicles,” *Oil Gas Facil.*, vol. 5, no. 01, pp. 47–52, 2016, doi: 10.2118/172471-pa.

[3] NEITI, “Nigeria: EITI Annual Activity Report 2013,” no. June, 2013.

[4] Kochetkova, L. I., "Pipeline monitoring with unmanned aerial vehicles," Journal of Physics: Conference Series, 2018.

[5] Austin, R., Unmanned Aircraft Systems: UAV Design, Development and Deployment, West Sussex: John Wiley and Sons Ltd, 2010.

[6] Kotarski, D., Benić, Z. and Krznar, M., "Control Design for Unmanned Aerial Vehicles with Four Motors," Interdisciplinary Description of complex System, vol. 14, no. 2, pp. 236-245, 2016.

[7] Cristina Gómez and David R. Green, "Small unmanned airborne systems to support oil and gas pipeline monitoring and mapping," Arabian Journal of Geosciences, vol. 10, no. 202, 2017.

[8] Villa, T. F., Gonzalez, F., Miljievic, B., Ristovski, Z. D., and Morawska, L., "An Overview of Small Unmanned Aerial Vehicles for Air Quality Measurements: Present Applications and Future Prospectives," Sensors, vol. 16, no. 7, 2016.

[9] Ejofodomi, O. A. and Ofualagba G., "Exploring the Feasibility of Robotic Pipeline Surveillance for Detecting Crude Oil Spills in the Niger Delta," International Journal of Unmanned Systems Engineering, vol. 5, no. 3, pp. 38-52, 2017.

[10] Ramon, B., Miguel, A., and Juan, M., "Design of an Infrared Imaging System for Robotic Inspection of Gas Leaks in Industrial Environments," International Journal of Advanced Robotic Systems, 2015.

Open Access
No. 34 part 2, April 2022, pp. 211-224

P- ISSN: 2220-5381
E- ISSN: 2710-1096

[11] Kelvin, N., "Mobile Remote Sensing: A Heterogeneous Linear Sensor Network for Trans-Alaskan Pipeline Leak Detection," Duke University, Durham, North Carolina, 2015.

[12] Omijeh, B. O., Oden, V. M., Joseph, K. J. and Erameh, J. A., "Design and Construction of a Quadcopter with Payload for Pipeline Inspection and Surveillance," Intl. J. of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 5, no. 6, 2016.

[13] Claudio Sciortino, Adriano Fagiolini, Member, IEEE , ROS/Gazebo -based Simulation of Quadcopter Aircrafts , 978 - 1 -5386 -6282 -3/18/$31.00 ©2018 IEEE.

[14] Quiñonez Y., Barrera F., Bugueño I., Bekios -Calfa J. 2018 Simulation and path planning for quadcopter obstacle avoidance in indoor environments using the ROS framework. In: Mejia J., Muñoz M., Rocha Á., Quiñonez Y., Calvo -Manzano J. (eds) Trends and Applications in Software Engineering. CIMPS 2017. Advances in Intelligent Systems and Computing, vol 688. Springer, Cham.

[15] Ícaro V. Igor A. Davi S. Luiz G. 2015 Trajectory Tracking Control of an Aerial Robot with Obstacle Avoidance IFAC Vol. 48, Issue 19, pp. 81 -86.

[16] W. J. Wang, T. M. Hsu, and T. S. Wu, “The improved pure pursuit algorithm for autonomous driving advanced system,” *2017 IEEE 10th Int. Work. Comput. Intell. Appl. IWCIA 2017 - Proc.*, vol. 2017-Decem, pp. 33–38, 2017, doi: 10.1109/IWCIA.2017.8203557.