AUTONOMOUS ONE WHEEL FLYING ROBOT

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ABSTRACT

Unmanned aerial vehicles (UAVs) are undoubtedly have great potential in the areas that are difficult to reach by human or ground vehicles. The autonomous unmanned aerial vehicles can control itself. The conventional UAVs have three-dimensional mobility but have landing and takeoff restrictions, mission time limitations, and usually are demanding to operate. The typical problem encountered on most sites is the unavailable of ground space for the vehicle to take-off and land. In this paper, a new autonomous one wheel flying robot configuration has been developed that shows great promise for aiding law enforcement personnel. This concept uses a VTOL, autonomous unmanned air vehicle to provide mobility to sensors and other payloads. On top of that, this unique design of autonomous one wheel flying robot has the ability to perform transition maneuvers between vertical and horizontal flights. This outstanding feature enables the robot to capture the performance capabilities from both fixed wing airplane and helicopter-like machines.

KEYWORDS: *Gyroscopic, single wheel robot, Vertical Take Off and Landing (VTOL), flying robot, sensor, balance detector, control unit, stand.*

I. INTRODUCTION

In recent years, the use of unmanned vehicles increase very rapidly across all over the world. Objects like unmanned aircraft, underwater exploiters, satellites and intelligent robotics are widely investigated as they have potential applications in many area like military, civil domains. They are developed to be capable of working autonomously without a human pilot. The challenge for this type of unmanned vehicles is that they need to deal with various situations that arise in much complicated and uncertain environments, such as unexpected obstacles, enemies attacking and device failures. Besides, they are required to communicate with technical personnel in the ground station. Unmanned aerial vehicles (UAVs) are undoubtedly have great potential for supporting law enforcement operations in the areas that are difficult to reach by human or ground vehicles. The UAVs that have the capability of autonomous operation are effective to perform these duties. The conventional UAVs have three-dimensional mobility but have landing and takeoff restrictions, mission time limitations, and usually are demanding to operate. The typical problem encountered on most sites is the unavailable of ground space for the vehicle to take-off and land. In these restricted environments, the UAVs that have vertical take-off and landing (VTOL) capability offer some distinct operational advantages. The UAVs that have vertical take-off and landing (VTOL) capability offer some distinct operational advantages.

1.1 Multi or Single wheel robot

In the single or multi wheel robot the main purpose of wheel is to give the robot stable movement. Now a days different type of wheel robot are develop and those are one or multi wheel robot. Example of this type of robots are Gyrover, Gyrobot, murata girl, The Gyrover which is created by CMU and the Gyrobot which is created by NUS. are both single wheel robot that are got stability by using mechanical gyroscopes [10][12]and the main advantage of using gyroscope is the robot can move any direction or any angle .More recently the development of a reaction wheel stabilized unicycle robot murata girl was announced by murata manufacturing co. Ltd.

1.2 Flying robot

The flying robot is a miniature sized robot designed to look like a fly that can be remotely controlled. Low-cost and small-size flying robots are becoming broadly available and some of these platforms are able to lift relatively high payloads and provide an increasingly broad set of basic functionalities. This enables even inexperienced pilots to control these vehicles and allows them to be equipped with autonomous navigation abilities [6][11]. Whereas most of the proposed approaches for autonomous flying focus on systems for outdoor operation, vehicles that can autonomously operate in indoor environments are envisioned to be useful for a variety of applications including surveillance and search and rescue. In such settings and compared to ground vehicles, the main advantage of flying devices is their increased mobility. As for ground vehicles, the main task for an autonomous flying robot consists in reaching a desired location in an unsupervised manner, i.e. without human interference. In the literature, this task is known as navigation. To address the general task of navigation one requires tackling a set of problems ranging from state estimation to trajectory planning. In recent years, there are an increasing amount of researches on automatic flying of intelligent systems. Those systems are generally called as flying robots or unmanned air vehicle (UAV). UAVs are defined as aircraft without the onboard presence of pilots. Today, lots of different UAVs model are available, and those structures are named with respect to rotor number or physical appearance. Those systems are widely used for military applications, search and rescue operations, agricultural disinfection, filming sports events or movies from almost any angle and transporting or controlling equipment. Earlier day some type flying robot are invented and These are Quad-rotor, Twin-rotor,Tri-rotor, Helicopter, UAV, VTOL, etc. In the literature, a few studies can be found for those types systems. In those studies, only twin-rotor system is used in (Castillo, P., Lozano, R., & Dzul, A., E., 2005), but in that project, two rotors have tilting mechanisms and they didn't use any passive controller. An autonomous four motor flying robots. Valetti, Bethke et al. describe a platform based on the RcToys Draganflyer used for experiments at Aerospace Controls Laboratory, MIT. This platform is controlled autonomously using a motion capture system. Autonomous landing is a challenging problem for flying robots. An autonomous landing maneuver depends largely on two capabilities: the decision of where to land and the generation of control signals to guide the vehicle to a safe landing.

1.3 Vertical takeoff and landing flying robot

Unmanned vehicles are important when it comes to performing a desired task in a dangerous and or inaccessible environment. Unmanned indoor and outdoor mobile robots have been successfully used for some decades. More recently, a growing interest in unmanned aerial vehicles (UAVs) has been shown among the research community. Being able to design a vertical takeoff [7][8] and landing (VTOL)-UAV, which is highly maneuverable and extremely stable, is an important contribution to the field of aerial robotics since potential applications are tremendous (e.g., high buildings and monuments investigation, rescue missions, film making, etc.). In practical applications, the position in space of the UAV is generally controlled by an operator through a remote-control system using a visual feedback from an onboard camera, while the attitude is automatically stabilized via an onboard controller. The attitude controller is an important feature since it allows the vehicle to maintain a desired orientation and, hence, prevents the vehicle from flipping over and crashing when the pilot performs the desired maneuvers. The most common configuration of vertically take off and vertically landing fly robot is the helicopter. The helicopter is capable of true vertical flight, including the ability to hover in place, fly forward and aft and from side to side unfortunately; the helicopter has many limitations and those are

(1)The area should be big enough for the helicopter to land within.

(2) The area is essentially clear, i.e., free or either natural or obstacles

II. RELATED WORK

2.1 Gyroscopically Stabilized Robot:

Self-stabilization of a single rolling wheel using a gyroscopic actuation was under several explorations for its importance in robotic applications [10][12] and the mechanical design consists basically of a gyro disk attached to internally suspended pendulum. Such arrangement provides a forward and reverse movement in which the reaction of the applied motor torque is counteracted by the moment of the hanging mass of the gyroscope.

2.3 Detecting Obstacle with IR (Infrared) Sensor

The basic concept of IR (infrared) obstacle detection is to transmit the IR signal (radiation) in a direction and a signal is received at the IR receiver when the IR radiation bounces [1][2] back from a surface of the object.
Here in the figure the object can be anything which has certain shape and size, the IR LED [8] transmits the IR signal on to the object and the signal is reflected back from the surface of the object. The reflected signals is received by an IR receiver [3]. The IR receiver can be a photodiode / phototransistor or a readymade module which decodes the signal.
In order to implement the IR obstacle detection, we need to understand the following

- We need to understand how to transmit IR signal using commercially available electronic components.
- Same way we also need to understand the IR receiver.

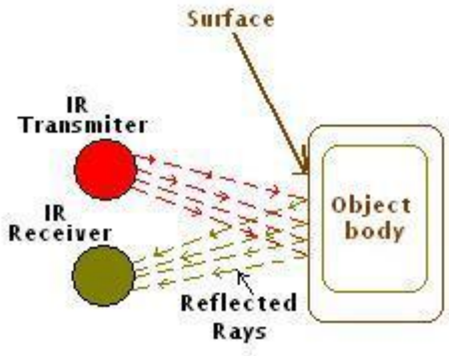


Fig1: IR (Infrared) Sensor

III. PROPOSED WORK

In our paper we have proposed a new type of robot named autonomous One Wheel Flying Robot (AOWFR) which is capable to control by itself autonomously. This robot can run in a very narrow path and can also land and take off on a very narrow ground.

3.1 Features of OWFR

The main features of our proposed AOWFR are

- It is more stable autonomous one wheel flying robot.
- It have an effective mechanism to reach the destination point by avoiding obstacle.
- It can fly up to 30 meters from ground using its flying instruments.
- It uses the Vertical Takeoff and Landing mechanism (VTOL) to fly.
- Its can land on its single wheel which is the main characteristics of AOWFR and landing in one wheel is the most challenging work because in the time of landing on ground robot should be stable.
- It can pass from a very narrow road as it has only one wheel. It can travel on the ground using it’s one wheel with keeping the balance.

3.2 Working Principle

1. Standing Condition:
In the standing time the four supporting arm spread to keep the balance of the robot. Also four flying motor and their individual blades are moving continuously for stability. The figure of robot in the standing time is given in below.

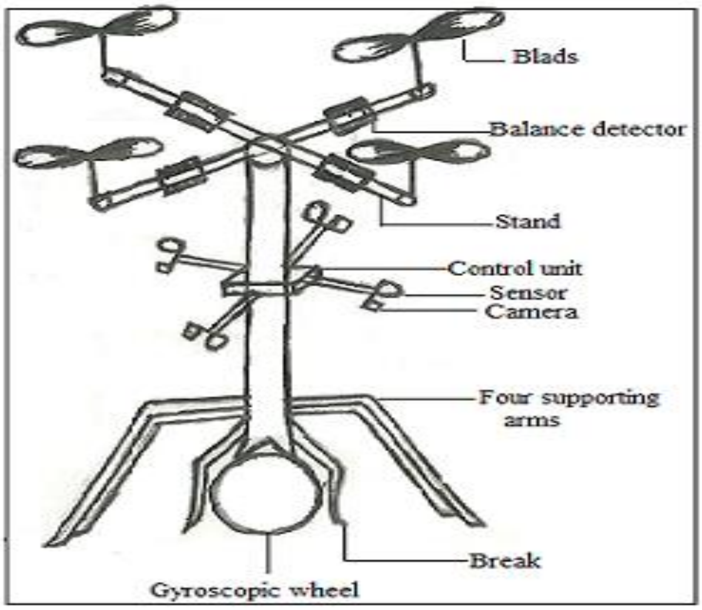


Fig 2: Construction of AOWFR

2. Flying Condition:
In the flying time robot have mainly two mode and those are Take -off mode and landing mode. Both mode are describe below one by one.
Terminologies
The following terminologies we have used in our algorithm.
Ld: Distance from the land.
Lr: Distance from ground when the arms are landed.

3. Takeoff mode:
Algorithm for take-off mode:

Step 1: As AOWFR can control by itself autonomously firstly to take-off from ground first it checks whether robot is in stable condition by balance detector. If it is in stable condition then it follow next step. If it is not in stable condition then it move from that place for some distance and then again check it stability condition.

Step 2: In this step it checks is upper surrounding view obstacle free? [If we don't check whether upper surrounding area is obstacle free or not then AOWFR cannot take-off properly. So for that use of camera is very impotent].If upper surrounding is free, then it goes to step 4. Else it goes to step 3

Step 3: AOWFR move 2 meter through one wheel and then repeatedly again it check is upper surrounding view obstacle free? If, yes then it go farther step. Otherwise again
It repeated from step2.The distance can be take any value, we have taken 2 m because if an obstacle is in there on the upper surround normally it do not take more than 2 meter.

Step 4: In this step robot spread its four supporting arms R1, R2, R3 & R4 mainly to stable the robot. In the time of Take-off as the fly motor start working so robot can unstable or fallen down on ground so to give stability we use four supporting arms.

Step5: Four valve are in vertical position or flying position as shown in figure.

Step 6: After getting stable, robot start it flying motor and start flying.

Step 7: In the flying time it Furl the four wheels otherwise it four wheel take some extra area and that may be create problem. For that it furl it's four wheel.

Step 8: As AOWFR can only capable to fly upto30 meter so In this step it Check is the altitude Ld 30 m ?, If yes, then increase the altitude. If no, robot flies parallel to ground.

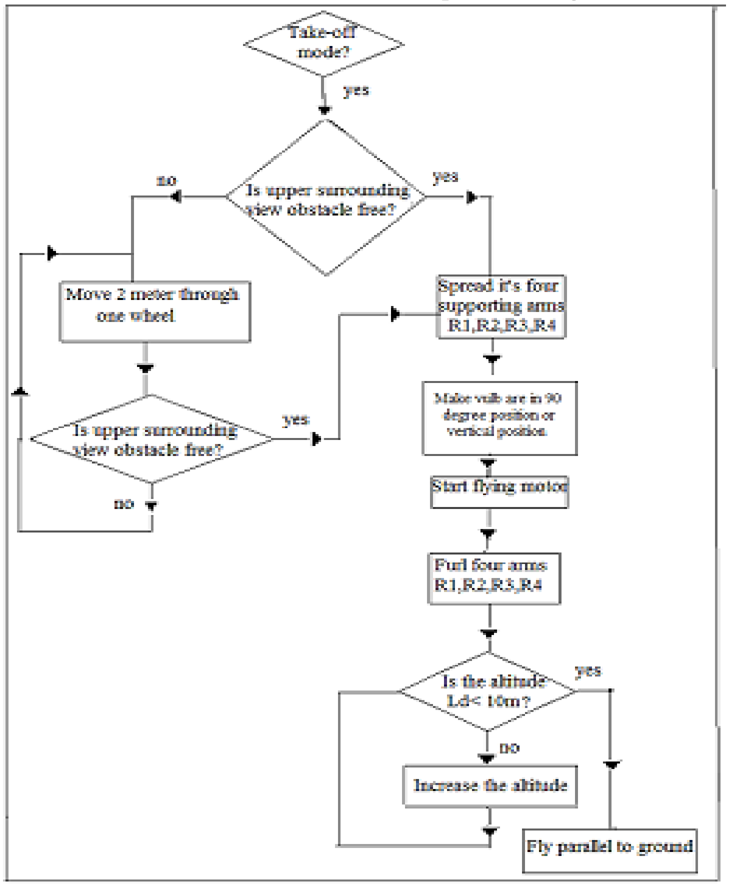


Fig 3: The Flowchart of take of mode of AOWFR

4. Algorithm of Landing Mode:

Step1: When the AOWFR need to land on the ground first it check whether the landing mode is activated or not? If the landing mode is activated then flow step2

Step 2: In this step first it stop horizontal moving then it calculates the distance from the land (Ld) by itself. This step is a very impotent step for landing so need very accurate calculation & gradually decrease the altitude from the land until it reach 1m above the land.

Step3: Ld is decreased gradually and altitude controller check is Ld< 1 meter? Each .when it reach 1m above the land then control unit check through sensor is the area where the robot is going to land is suitable or not?, if it finds that the land below is suitable for landing then it goes for further step .if it finds some water or something not suitable for landing then it move some distance again check for suitable place It will do this until it gets the suitable place.

Step4: After getting a suitable place to land AOWFR spreads its four supporting arms R1, R2, R3 & R4 because in the time of landing robot should be in stable condition so to give the stability four arms are use. These four arms 90 degree apart from each other and the angle between each arm to the wheel of AOWFR is 60 degree. These are to give the stability if the land is not smooth.

Step5: Now after landing the system checks if the AOWFR is stable or not? Means land is smooth enough? Now if the system finds that AOWFR is stable then it goes to step 6. If no then it move 2 meter horizontal and again check the condition.

Step6: Now when the AOWFR is stable the flying wheels are stopped. Altitude controller decreased by decreasing the distance from the wheel to land i.e. l Lr. Each step Lr is decreases by 0.1cm. Now the system checks if check is Lr=0? [i.e the wheel is landed?] If AOWFR is landed then the system goes to step 8. This loop is continued until Lr=0.

Step7: Now after landing the system checks is AOWFR stable? If it is found to be stable i.e. the wheel landed properly and if the wheel can control the AOWFR now then the system takes off the four supporting arms. This is done by the procedure by checking the stability like 1st the system take off two opposite arms by 2cm and check whether robot is stable if stable then it take off another two arms.

Step8: Now after taking off the four arms the system does its works by the single wheel. Thus the AOWFR is landed successfully.

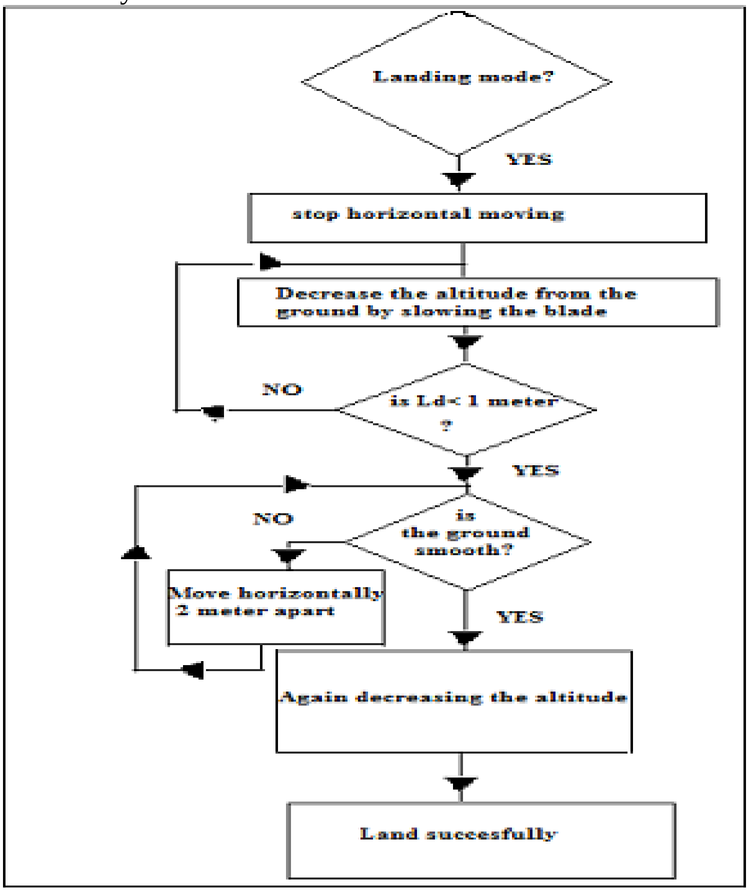


Fig 4: The Flowchart of landing mode of AOWFR

5 Algorithm for travelling through ground mode:

Step1:When the control unit get command for travelling through ground at first I the valve of the four arm are in 0 degree or horizontal to ground and four flying motor start rotating and it keep the robot more balance.

Step2:As before moving four arms are touching the land ,in this step Four supporting arms then furl before the robot start moving.

Step3:In this step control unit determine the direction of object where the robot have to go.

Step4: Control unit all time check the balance of the robot.

If it is lean in left side then increase the speed of left motor

& decrees the right motor & for lean in right control unit make opposite operation to stable the robot.

Step5:In this step it check is any obstacle in front of the robot?
If yes, then push the break and by sensor it check is any obstacle located in right side? If yes then move robot 1 meter left side and if no then move to the 1 meter right side. then again go to step 4. If no, move towards the direction of object.
Step6:It check whether robot reach to the object ?If yes then push the break to stop the robot. If no then again start from step4.In this away robot finally reach the object.

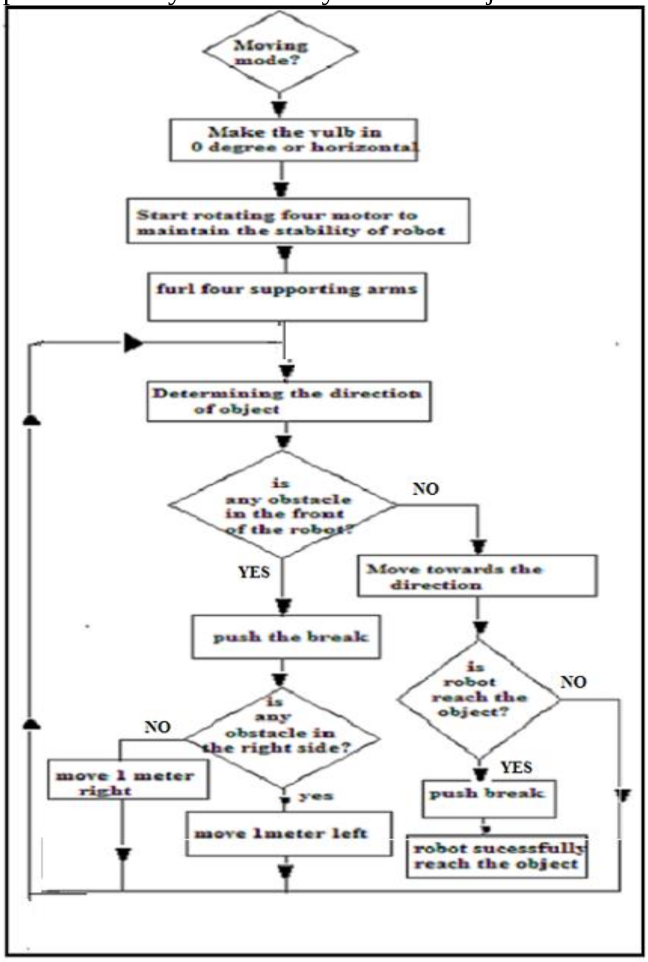


Fig 5: The Flowchart of travelling mode of AOWFR

IV. CONSTRUCTION OF OWFR

1. Balance detector

When the robot travelling through land by one wheel that time the balance of the robot is the main factor. To maintain the balance the control unit has to know whether the robot is in balance condition or not? The balance detector indentify the unbalance condition and the portion for which the robot has unbalance. Balance detector is a close vassel containing nearly full of conducting liquid and few portion of air and two metallic conductor plate that attached two side of the vessal.

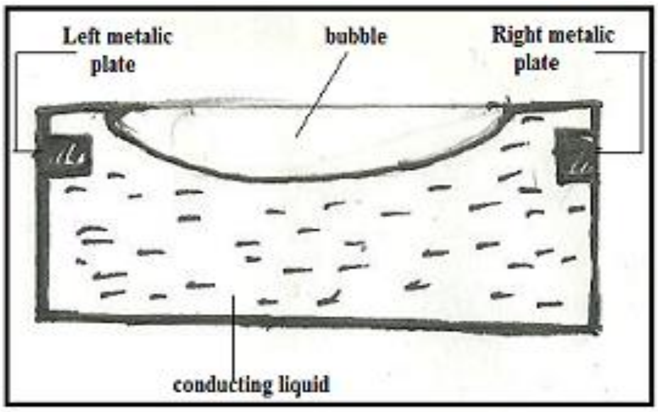
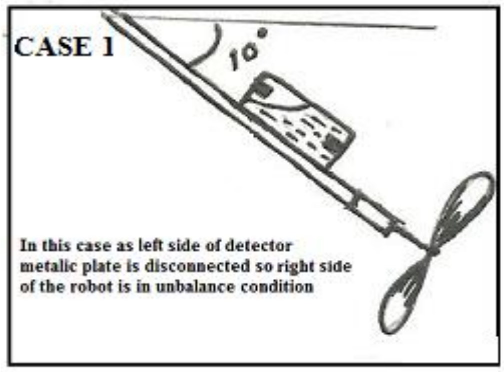
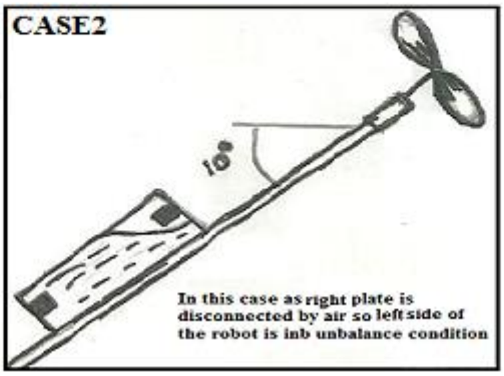


Fig 6: Balance Detector

Working Principle

In the balance condition the air babble will be on the middle portion of the tube at that time two conductor plate are in conduction state through conducting liquid. Now when the robot is in unbalance condition and 10 degree or more than 10degree lean in the left side that time one plate cover by the air bubble and another one is cover by liquid and that result two plate are disconnected and they loss conductivity. So when the two are disconnected if left plate is cover by bubble then right side of the robot is in unbalance condition and vice visa. So in this way balance detector detect the unbalance portion of the robot.





2. Sensor

It is the device which sense the obstacle in the front of the sensor. In our robot we use total 6 sensor are use. As each sensor cover 90 degree each. So four are attach surround of the robot and two another sensor are place upper portion and lower portion of the robot respectively. In this robot we program the sensor in this way that when an obstacle comes in between 30 inch, then the sensor are sent a signal to the control unit.

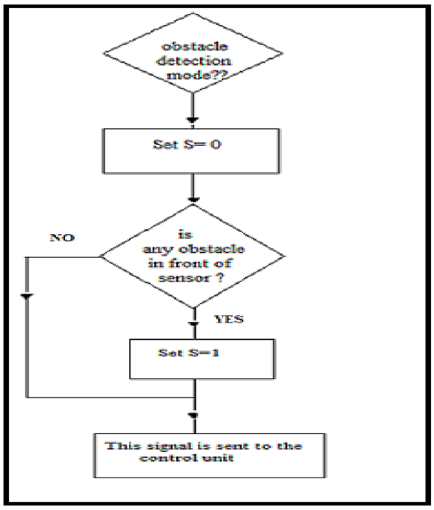


Fig 7: The Flowchart of sensor mode of AOWFR

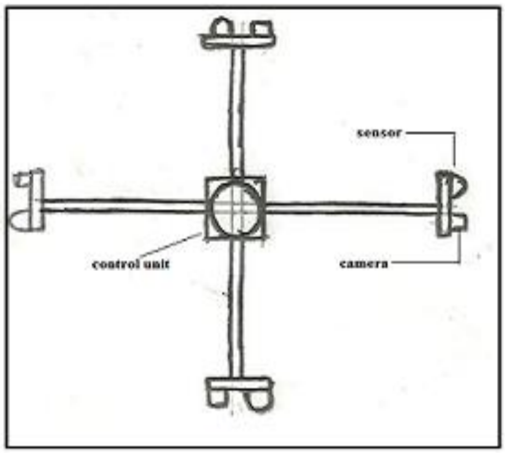


Fig8: Diagram of stand

3. VALVE

In valve which have a specific feature and that is it can move either horizontally or vertical (90 degree) and as on the valve the flying motor with their corresponding blades are connected. It help the robot to keep balance in flying time as well as moving on ground time.

4. Gyroscopic

A gyroscope is a device for measuring or maintaining orientation, based on the principle of angular momentum.

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5. Camera

In OWFR camera is a very important part. Mainly CCD video camera is use to see the landscape means to view the surrounding environment.

Mechanically, a gyroscope is a spinning wheel. In OWFR gyroscope is the only one wheel we used.

6. Rotor Blades

The blades of AOWFR are long, narrow airfoils with a high aspect ratio, a shape which minimizes drag from tip vortices (see the wings of a glider for comparison). They generally contain a degree of washout to reduce the lift generated at the tips, where the airflow is fastest and vortex generation would be a significant problem. Rotor blades are made out of various materials, including aluminum, composite structure and steel or titanium with abrasion shields along the leading edge. Rotorcraft blades are traditionally passive.

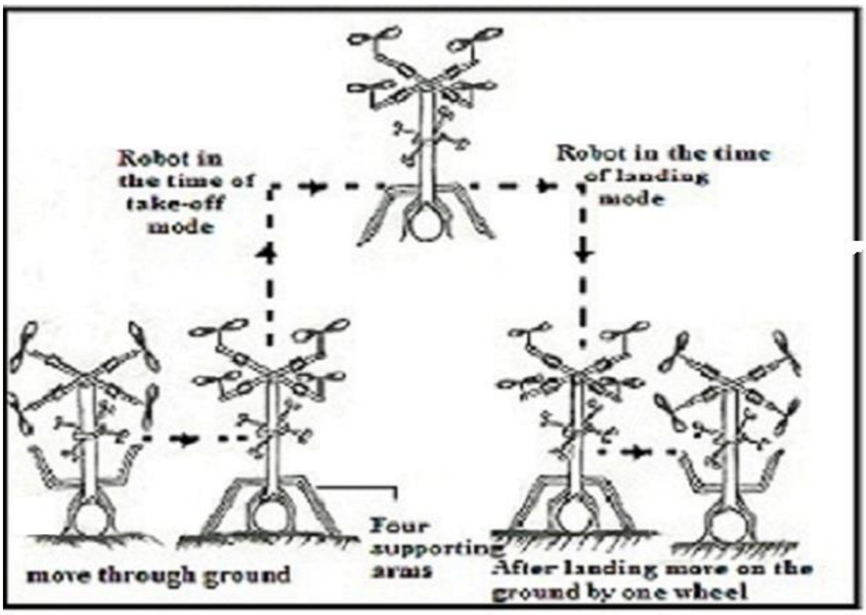
7. Supporting arms

Four supporting arms R1, R2, R3 &R4 are there in AOWFR. Mainly those are used to stabilize the robot. In the algorithm of landing we have use Lr. where Lr initial value is the height of supporting arm. Those four arms can be made by any metal only the restriction is it have to be very flexible in nature.

8. Control Unit

The control unit controls the whole operation of robot standing, takeoff landing moving etc and communicate with all unit in the robot. In other word the control unit is the brain of the robot [4][7]. As our robot is autonomous so our control unit would be programmable with microcontroller and its necessary equipment .now the microcontroller is program in such a way that our robot can work in a specific way and control unit consist a transmitter to transmit information captured by camera. At first control unit check the mode operation and then operate the whole system through the specified algorithm .

FLYING MODE OF OWFR



V. SIMULATION RESULTS

In order to evaluate the performance of the new algorithm on VTOL, The comparison done in between probability of landing verses smoothness of the land, effective work of control unit vs frequency of control unit and Time taken to land verses the number of obstacle. The simulation results were run on MATLAB 7.8 in a designed virtual environment.

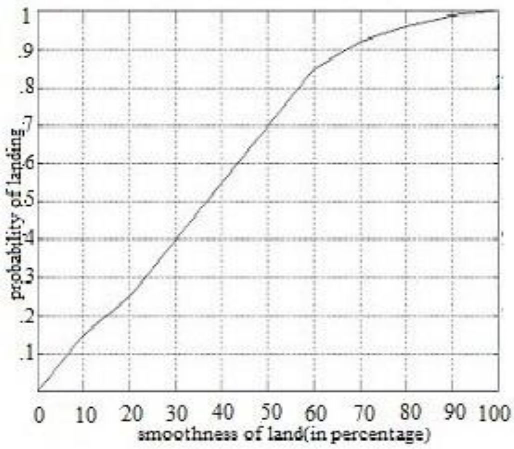


Fig-9: Simulation results of how the probability of landing varies accordingly to the smoothness of the ground

In figure-9 comparison between probability of landing verses smoothness of the land. From the result it conclude that with the increase of smoothness of land, the probability of landing become high. when smoothness of land is perfect means 100(in percentage) the probability of landing become nearly 1 and when the smoothness of land is very bad means nearly 0 (in percentage) then landing probability become nearly zero. In this operation camera plays very key role because if somehow camera cannot capture in picture of land then all the entire system cannot work properly.

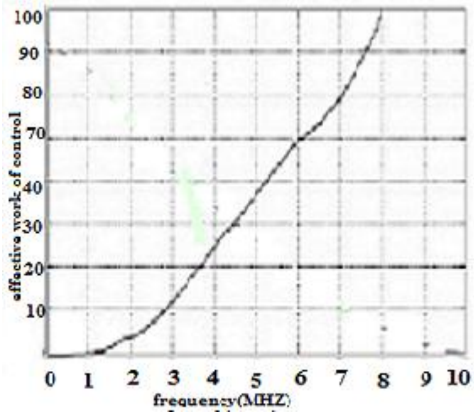


Fig-10 Simulation results of how effective work with respect to frequency of control unit

In figure-10 we plotted in between effective work of control unit vs frequency (MHZ) of control unit. The graph shows that with the increase of the frequency of control unit the efficiency of the control unit increase.

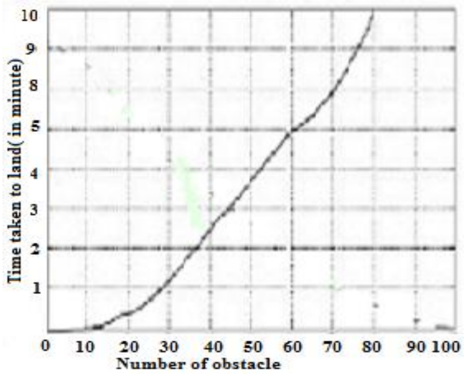


Fig 11: Simulation results of how much time AOWFR will take to the number of obstacle

In figure-11 it shown the simulation results between the time taken to land (in minute) verses number of obstacle. The graph says that with the increase of the number of the obstacle, the time taken to land the robot is decrease .when the number of obstacle is very high simulation says near about 9 minute is required to land the robot but if there is no obstacle than time required by robot is only few seconds. So we have found that AOWFR will more efficient than previous type of robot.

VI. CONCLUSION

This paper proposed an autonomous AOWFR (one wheel flying robot). It uses the Vertical Takeoff and Landing mechanism (VTOL) to fly. An algorithm for vertical Takeoff and an algorithm for landing mechanism proposed. First description of Gyroscopically Stabilized single wheel & multi wheel Robot then flying robot then Vertical takeoff and landing flying robot is given. Then description of our autonomous AOWFR and its main feature given. Then we have shown how those feature can be realize .Then a specific algorithm and flowchart of Take-off mode, landing mode, grounding mode respectively given. Then description about balance detector, sensor, control unit. Then simulation of the OWFR with respect to ground nature and how the probability of landing it varies accordingly to the smoothness of the ground. The calculation how effective work done with the increase of frequency of control unit is given. In our final simulation the calculation of the time required to land which is also a function of the number of obstacle. These results show that AOWFR is working very effectively.

VII. FUTURE WORK

In future we will be concentrating how the AOWFR can be more stable and efficient. How it can be used in all three condition like in water, in sky, in ground. Also by using it advantage of having both one wheel & flying facility how it can be use in space.

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