Experimental study of UAV for Precise Obstacle Tracking and Detection

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Abstract-- **The design of multirotor vehicles is always based on a scale model and there are many conventional multirotor designs where there are irregularities in quadrotor.Also there include individual requirements testing and validating of UAV components. This innovative channel-like design protects the propeller from external objects and supports thrust that offers maximum efficiency. It also contains special pores on the surface of the duct that help reduce noise. In this work, the design was validated by experimental analysis such as wind tunnel and CFD analysis of many structural components. The structure of the quadcopter consists of a unique metal fiber laminate that offers maximum load capacity. The propulsion system design was also carried out both computationally and experimentally, with most of the results being validated. The current era was also the era of artificial intelligence, so the present work focuses on the implementation of artificial intelligence techniques for quadcopter obstacle detection and navigation in an unsafe environment. The method used for obstacle detection consists of using the Firefly algorithm controller, which provides an efficient solution for obstacle detection and multi-navigation for both static and dynamic environments. This Firefly algorithm is a Probable Fuzzy Logic (PFL) and Matrix Based Genetic Algorithm (MGA) hybrid and maintains a hybrid multi-copter navigation controller algorithm for obstacle detection and trajectory planning. This is simulated in MATLAB software and compared to the experimental setup in real time. The developed unmanned system (multi-copter) offers a unique design with efficient high-level detection, tracking and obstacle detection capabilities.**

Keywords----UAV testing methods, multi-copter, unmanned aerial system, FML. Channel, Firefly Algorithm, PFL, MGA

I.INTRODUCTION

The proposed research focuses on the field of unmanned aerial vehicles and addresses various factors applied in the field of unmanned aerial vehicle systems and unconventional modern design with innovative designs that respond to different aerodynamic parameters. This task will examine various computational methods for multi-copter design and development, as well as high levels of reconnaissance, tracking, and artificial intelligence (AI) for obstacle detection. The deepening of the diploma thesis is divided into four main sections. The first section of the introduction provides the background and inspiration for the proposed research [1]. The second section describes the research goals and their application to improve human life, creating special fields of application in the fields of technology and science. A new approach to the proposed research work is presented in the third section. Finally, in the fourth section, a brief reference to all chapters of the research work concludes.

The preliminary study of the UAVs must be carried out using the available documentation. The choice of design parameters for the multi-copter must be considered by some of the generalized mathematical equations[2]. Geometric modeling of the multi-copter is done with Solid Works software Computational analysis and experimental analysis of geometric modeling should be performed in a Solid Works analysis tool and experimental analysis in a low subsonic wind tunnel. Material selection by optimizing its properties and material selection should be based on applications. It is necessary to perform mechanical tests of the material to identify the breaking characteristics of the material. The development of the drive system is carried out and various drive components are optimized to achieve high energy efficiency. The calibration and experimental analysis of the drive system is performed in a test setup. Developmentof route planning, obstacle detection and collision avoidance with artificial intelligence using the Firefly algorithm. A computer and experimental simulation of the trajectory planning and obstacle detection system was performed and the results.

II.LITERATURE REVIEW

Multi-copters are most likely wireless drones used for various purposes. Those Multi-helicopters are one of the most complexes flying machines due to their versatility several types of tasks. The first multi-rotor vehicle with fixed rotors was proposed by De Bothezat in 1923 but due to poor research and development during that decade which delays the construction of such machines. His main problem was related to his Instability due to high payload. [1] Since then, the development of various components such as batteries, actuators, sensors, etc., resulting in a controlled machine. Today UAVs like multi-copters are not only RC controlled toys, but also can perform various feats Application and also support almost 5-6 kg payload [2].Many places the application of Drones are used as flying robots for various identification-based services. The supervision becomes a daunting task during natural disasters such as earthquakes. In these Situations in which "Unmanned Aerial Vehicles (UAVs)" have proven themselves Surveillance activities. In addition, military applications are expected to arrive soon. Multi-rotors are considered the most stable wireless drones. Multi-rotors (Tri, Quad, Hex, Octal, etc.) a type of UAV that will become a major research platform in aviation history. Under this makes quad rotors more efficient with a stable and simple structure for various maneuvers [4]. Since the hexa-copter and the octa-copter are also in demand if there is one have to carry a heavier payload, e.g. B. Carrying a camera for aerial photography or falling packets etc..

A. *Design and development of airframe*

The resulting dynamic mathematical model is then calculated and used to simulate the system dynamics. Since the actual data collected from the given system is used in the modeling process, an extracted dynamic model using the system identification can be considered more accurate and created in less time than the simulation methods based on the physical system. In a world where accuracy and simulation time are two critical factors in model development, the benefits of system identification are significant.

B. Propulsion system design and evaluation

The design of multi-copter propulsion systems can be divided into four main categories, viz. Propeller design, motor design and evaluation, ESC modeling and battery performance Optimization. Fixed propellers are always used for the construction of the multi-copter drive Power depends on thrust and torque [13-16]. The multi-copter is often driven by fixed propellers and their performance depends on it thrust and torque. Every propeller has two parameters, namely diameter and pitch. The step of Spiral is the distance the spiral would move forward in one revolution in a, constant medium. For maximum lift, the propeller pitch should be high and the angle of the blades should be more. The propeller designation is given as 12 inches and 8 in diameter no inch, then it will be referred to as 12 x 8. [7-8].Multi-copter typically uses brushless DC motors, which can be modeled as permanent magnetic DC motor [14]. The no-load current required to overcome mechanical friction and air friction in the motor, as well as magnetic hysteresis and eddy current losses in the engine and is approximately constant at a certain engine speed.

C. Path p2lanning, obstacle detection and collision avoidance

Drone navigation planning and optimization with various Algorithms like ant colony, particle swarm, and matrix based algorithms and many more intelligent algorithms. [10]. With the increasing application of UAV and its range is the main requirement Collision avoidance, which plays an important role in trajectory planning. For these problems there are many solutions that provide a suitable solution to avoid collisions and obstacleDetection, but these solutions cannot be implemented due to various disadvantages. There is two existing solutions available, the first solution to avoid collision is to retract the vehicle opposite direction [14-16] and the second solution is based on SLAM that avoids Collision by mapping, positioning and navigating the map during positioning and the mapping is based on a complex SLAM algorithm [11- 15], [16]. As for the first Split compared to other solutions does not limit these missions by collision to avoid this, SLAM algorithm is required, which has good memory and processing power Power as mentioned in simple solution due to its complex nature. [13] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction.

D.Firefly Algorithm

On Natural view Firefly, which is also a winged beetle, is a member of the Lumpyride family and Because of their ability to produce light, they are often referred to as flash bugs[20]. The light is generated by a chemical process of oxidation of Lucifer in the presence of enzymes Luciferase, occurs quickly. This process that creates light is called as Bioluminescence and fireflies use this light to glow without wasting heat energy. [5] discussed that the activity related status data will be communicated consistently and shared among drivers through VANETs keeping in mind the end goal to enhance driving security and solace. [11] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation.

III. STRUCTURAL DESIGN AND DEVELOPMENT OFMULTICOPTER (QUADCOPTER)

A. Airframe configuration

The configuration of multi-copter is X type where all the booms meet at the centre and the propeller are placed at the end of arms. The configuration of X- type. This configuration gives better maneuverability as rotors are involved in pitching and rolling moment and this gives a less obstruction of the forward movement due to this benefits this configuration is most popular this configuration of multi-coptercommon form type which houses four motor and four propellers attached at the end of all three booms[22]. This quad copter configuration is a common form type housing four motors and four Propellers attached to the end of the two booms. The usual shape used in our design is given in Figure 1

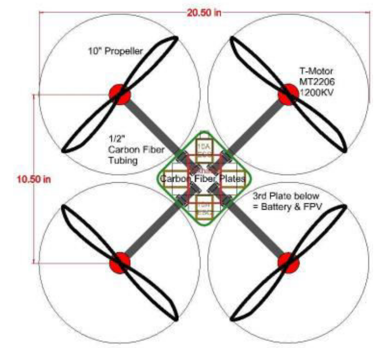

Fig 1 – X- type Quadcopter Configuration

B. Airframe centre of gravity

Multicomputer must have its center of gravity on the central axis, which provides better stability; otherwise, it will cause an excessive moment, resulting in a fracture design. So for this calculation we used the Center of Mass and Mass Detail tool in the Solid works software. As the geometry is complicated, so it is calculated using Solid works. They follow result from the formula,

Weight estimation;

$$\text{Where, } W_T = \sum_{i=0} max\ W$$

Total weight of the multi-copter is given by

$$WT = We + Wpow + Welsys + Wb + Wp$$

C. CFD analysis of quadcopter disc frame

The low weight Multi-copter and UAV classes (about 2-10 kg) are comparatively portable and easy to handle assemble if desired. VTOL (Vertical Take-off and Landing) capabilities are key attributes for the multi-copter. That Models like the quad-copter, the .hexa-copter are projects that have been explored inthe past few years. The growing interest on the part of multi-copters goes in the direction of more innovative research into multi-copter aerodynamics, propulsion system. Computational Fluid Dynamics (CFD) is a very important tool that is widely used in the field of aerodynamic applications and flow visualization applications[20-22]. He delivers Numerical solutions to governing equations such as Navier-Stokes throughout the fluid Domain. This technique gives the opportunity to simulate and analyze the complex Problems without losing the integrity of the problem thanks to a simplified flow field models.

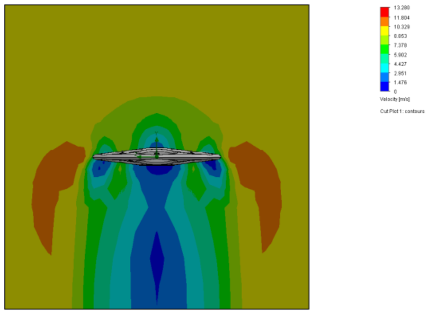

Fig 2 – CFD Analysis of Disc type

IV.PATH PLANNING OBSTACLE DETECTION AND COLLISION AVOIDANCE

The drone to perform an intelligent calculation of an optimum or a near optimum. Flight path between the starting position and the final control points or fulfill their mission with specific restrictions such as path length, obstacle avoidance, etc. also related to obstacle avoidance. The development of the trajectory planning process has a rapid pace Growth in recent years and the problem is solved specifically with the help of Advance

Algorithms like swarm intelligence, genetic algorithms, ant colony optimization, fire Fly, particle swarm optimization, simulated annealing etc. The Firefly algorithm is a well-known heuristic algorithm inspired by blinking Behavior of fireflies discovered in 2008 by Dr. Yang was developed[22-28]. It's stochastic Nature, because it follows chance and works on the principle of trial and error find the optimal solution in a realistic time frame. The general limitation of flight path planning and obstacle avoidance between UAVs and and other Route objects are: It should have a predefined target with all start and end positions. It must have predefined initial and final speed ranges. It must have a single route target with a preset airspeed variation.

A. *Firefly Algorithm*

Light attractiveness and intensity are the most important key factors for the Firefly algorithm. The attractiveness of the firefly is determined by its luminosity, so luminosity is the main objective function of the algorithm.

$$Ir=Is/r^2$$

Let i be the luminosity of a firefly and x its position then we can say that can be any for the equation

$$I=Ioe^{-r}$$

In the practical exam, the attractiveness function for the equation

$$\beta= \beta o/1+\gamma\ r^2$$

A demand the attractiveness changes significantly from The defined characteristic distances than an exponential function, the above function, if needed, can conveniently be approximated by is the attractiveness at As is often the case, the Firefly algorithm to compute Attractiveness of firefly is proportional to light intensity which is defined by Where is the original light intensity. In order to avoid the singularity the expression, the combined effect of the inverse square law and absorption can be approximated as the following Gaussians form − γ , the light intensity I varies with the distance r is 0 r γ depends on the distance between the two fireflies i and j. The intensity of the light varies according to the variation of the avoidance distance from the source to the target r and of the medium of absorption of the light.

$$X1 = x1+\beta oe^{-\gamma r2i,j}$$

Thus, the light intensity I r is given with respect to the intensity of the source using the inverse square law and for the light absorption coefficient.

B. OBSTACLE AVOIDANCE BEHAVIOR

Navigation is a difficult task for any multi-copter when the environment is unsafe. That the uncertainty may relate to the change in the state of the obstacle or the target. The present obstacle in the area may vary in shape and size. To accomplish the task of efficiency Navigation, the multi-copter needs an obstacle avoidance mechanism to avoid collisions Obstacles in the unsafe environment. The Firefly algorithm produces the number of random fireflies near the obstacle and the brightest firefly is selected from the group Brightness. The brightest firefly is selected so that it should be the outermost Safety distance to the nearby obstacle[31]. The multi-copter takes the position of the new selected fireflies and the search for the next brightest fireflies begins to safe and optimal path generated.

Then the distance between the multi-copters and the near obstacle;

$$D_{RO} = (X_0-X_r)^2 + (Y_0+Y_r)^2$$

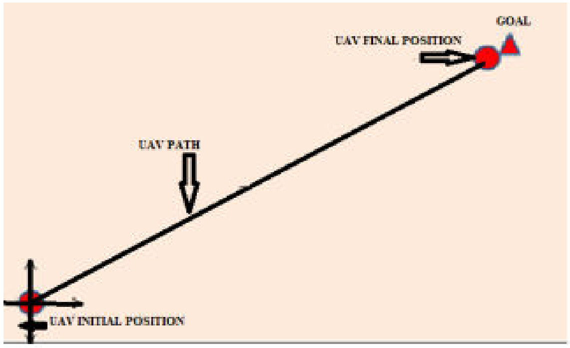

Fig 3 – Navigation of multi-copter in obstacle free environment

V. UAV TESTING METHODS

AS drone test ensures your product is compliant with all relevant UAS and drone legislation in your target market. Testing and certification can minimize the risk of noncompliance and product liability. The main components of a UAV can be divided into three main categories: (I) the aerial platform, which includes the airframe, the navigation system, the power system, and the payload; (ii) the ground control station (GCS), which allows the human control from a remote emplacement; and (iii) the communication system.

A.Propeller Balancing

Hub balancing is done by carefully drilling very small holes (say 2mm diameter) on the lighter side of the back of the hub, and filling the holes with a liquid ballast material or small pieces of lead, or perhaps fishing shot, sealed in[28]. Obviously the lighter side will be identified when using your prop balancer.

Carbon fiber balancing,

The simplest things you can do to make sure that your drone flies perfectly is to balance its props. If the props are not balanced, the heavier blade will cause excessive vibration which will cause extra wear on your motor. It will also make taking any video almost impossible. Balancing your drone's props is a fairly simple task.

Fig 4 – Carbon Fiber Propeller Balancing

B. Battery Maintenance

The electrically powered unmanned vehicle or multi-copter sows a different behavior because it was the same weight throughout the mission. Battery technology is currently based on Polymer lithium battery which compared to other batteries such as battery [27] provides the best results NiCd, Lipo, etc. The general characteristics that the lithium polymer battery shows in the top position are shown in the table below: NiCd, Lipo, etc. The general characteristics that the lithium polymer battery shows in the top position are shown in the table below:

TABLE-1 - GENERAL CHARACTERSTICS OF RECHARGEABLE BATTERIES

Battery Specific	*Specific energy (wh/kg)*	*Practical Specific energy (Wh/kg)*	*Speific power (W/Kg)*	*Cell Voltage(v)*
NiCad	240	60	150	1.2
Nigh	470	23.85	200 – 400	0.94 -1.2
Li- Ion	700	100- 135	250 – 340	3.6
Li- Po	735	50.7- 220	200 – 1900	3.7

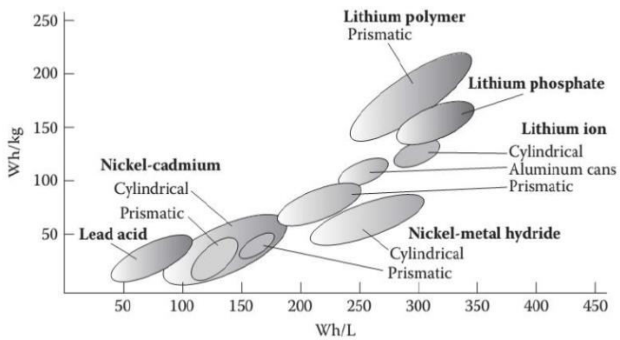

Fig 5 – Specific energy vs Energy Density of several types

C. Thrust checking machine and estimation

Drone thrust is the amount of upward force your drone can produce when at full throttle. You are probably not the only one with a juvenile snicker when reading "thrust" so many times, so lets' just get it out of the way. This is the power being delivered by the engine at a certain thrust or velocity. The propulsive power of a jet engine increases with its speed. [15] discussed about Positioning Of a Vehicle in a Combined Indoor-Outdoor Scenario, The development in technology has given us all sophistications but equal amounts of threats too. This has brought us an urge to bring a complete security system that monitors an object continuously.

Thrust stand design,

The design is separated into 3 segments, the mechanical design, the electrical design and the software design which will in this case consist of the code for the Arduino and the code for the GUI that I will be running on my laptop. Let's begin with the mechanical design. Those would be all of the 3pieces necessary for putting this whole thing together. As we previously mentioned, we attached everything together using some wood screws and some glue. Drill pilot holes into the before driving in the screws, which caused a few cracks[20-23], but after gluing it and clamping it together, it turned out great. The whole construction looks like. It's roughly 400mm by 300mm which isn't that small, but I wanted it to be stable and I also wanted the option of being able to test out bigger motors and propellers. With that part done, it's time to take a look at the mounting for the motor and the load cell.

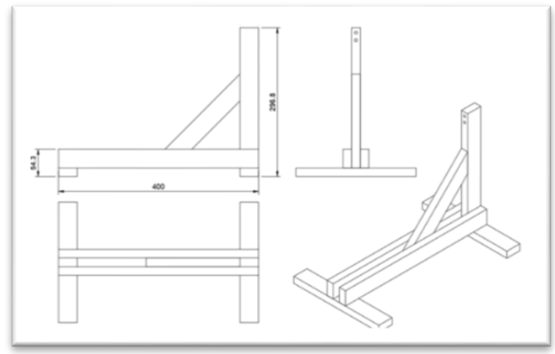

Fig 6 – Dimension of whole thrust stand length

Thrust calculation,

Double the drones weight in order to calculate the minimum amount of thrust. Gives thrust based on momentum theory, commonly used rule is that velocity of air at propeller. Del(V) = Total change in air, Velocity ratio = 2:1 , therefore, rpm = 4000 and 6000rpm.

$$V=1/2\ del(v)$$

Calculation based on drone,

For quad-copter,

Thrust = 300gms/ 4 = 75gms per motor thrust

For hexa-copter,

Thrust = 300gms/ 6 = 50 gms per motor thrust

For octa-copter,

Thrust = 300gms/ 8 = 37.5 gms per motor thrust

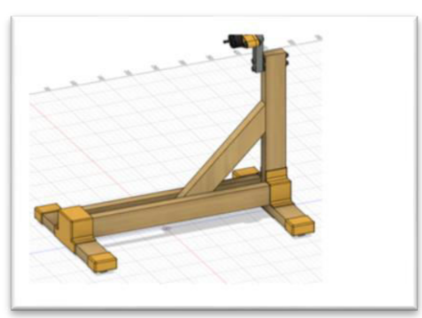

Fig 7 – The whole Thrust Measuring Stand

D. Servo Testing

CCPM Servo Tester is a small, compact module for monitoring the performance of servo motors such as synchronization, steering and ESC

(Electric Speed Controller [28]. CCPM Servo Consistency Master/Servo Tester is a low-cost, low-power device that can test three servos simultaneously. The tester requires a maximum of 6 volts for normal operation. It also has an Electronic Speed Controller (ESC) that is used to check the motor's current directions[30]. The tester does not require a transmitter or receiver to generate signals. It can be used to check faulty servo motors before using them in different projects.

Fig 8– Servo Tester

Mode of testing,

The wiring is quite simple. Connect a power source of no more than 6 volts to the tester's input block. The servo to be tested is connected to the output block of the tester. Now select the operating mode by pressing the operating mode selector switch. The movement of the motors depends on the selection mode.

Automatic mode

If we choose the automatic mode, the servo motor will automatically rotate to and from its maximum angle as soon as the tester is powered. Because it spins like a windshield wiper.

Neutral mode

If we choose the neutral mode, the motor will move to its factory set position.

Manual mode

If we select manual mode, we can rotate the servo motor at our own pace with an adjustable knob on the tester. As shown in the component diagram, the three LED indicators come with a servo tester module to allow the user to identify which mode the tester is operating in.

TABLE 2 - CCM SERVO TESTER PIN CONFIGURATION

Pin name	*Function*
INS	Signal input pin
IN +	Power supply pin
IN -	Ground pin
OUT_S	3*3 connector to connect three signal outputs to three servo motors
OUT +	Servo motor pin
OUT -	Servo motor ground pin

D. weight estimation

The total weight W of the UAV is simply the sum of the weight of all of the individual components.

Tw = w(structure) + w(components) + w(payload

UAVs payloads in excess of 500 pounds. Although the average drone can carry a few pounds, many heavyweights for professional drone pilots have a higher weight capacity, sometimes around 25 or 50 pounds[31]. The number varies from drone to drone; each drone is built to carry payloads according to its purpose. There are more types of drones, but the average drone payload number ranges from 0.3 to 2 kg, while a carrying drone can move 20 to 220 kg. [7] proposed a novel method for secure transportation of railway systems has been proposed in this project. In existing methods, most of the methods are manual resulting in a lot of human errors. This project proposes a system which can be controlled automatically without any outside help. This project has a model concerning two train sections and a gate section.

"Initial Weight Calculation" you most likely find masses listed in grams. Given that weight is just mass multiplied by the gravitational acceleration constant "g", mass in grams with be just fine. We do recommend calculating the weight from the mass for your own benefit, especially if grams or kilograms aren't intuitive to you. In fact, if you live at an especially extreme altitude you will be thankful for sticking to grams because weight will be subject to a possible change in "g" but we degrees.As you refine your design you will want to make sure to include everything that comprises your quad-copter including any additional wires, screws, etc [31-35]. Howe ever, you may not need any of those miscellaneous items depending on the connections among your equipment

TABLE 3- WEIGHT ESTIMATIONS

Item	Mass (g)	No of items	Total mass per item(g)	Total weight per item (N)	Total weight per item (b)
Flight control	66.3	1	663,300	0.650	0.146
Frame	282	1	282.00	2.766	0.622
Battery	331	1	331.000	3.247	0.731
Motor	7.72	4	7.720	0.076	0.017
ESC	14	4	220.000	2.158	0.486
Propeller	15	4	56.000	0.589	0.132

VI.RESULT AND DISCUSSION

The study of experimental setup and analysis such as Computational Fluid Dynamics (CFD), Finite Element Method (FEM). This chapter deals with the comparison of all discussed experimental, theoretical and simulation results. Simulated and experimental evaluations of each performance optimization condition are systematically presented on the same environment setup.

A. Test Result for Material Testing for Multi-copter structure.

Carbon tubes of strength that make it a better choice for the aerospace industry. The carbon tube can have an increase in properties in combination with another material. Metal fiber laminates offer very good properties for structural applications, especially in relation to impact properties. [3] emphasized that people who are visually impaired have a hard time navigating their surroundings, recognizing objects, and avoiding hazards on their own since they do not know what is going on in their immediate surroundings. [9] proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs).

B. Path planning, Obstacle detection and collision avoidance navigation controller analysis

We examined different navigation controls for path planning, obstacle detection and collision avoidance. These controllers are examined individually for their simulation and experimental analysis. This section presents the performance analysis of the discussed controller under the same environmental conditions[29-30]. The same environment configuration was provided in the case of multi-copter browsing. The analysis is presented in both a static and dynamic environment. This shows the result of the simulation by the single controller in the static environment using a quad-type multi-copter. This reflects the navigation of the multi-copter in the presence of the dynamic obstacle. The simulation results for optimal path length and minimum sailing time are gathered through many trials and the best path is selected for a single controller under the same environmental conditions[26-28]. The FA-MFA hybrid controller delivers the best results in terms of trajectory optimality, navigation time, and obstacle detection and collision avoidance on a single controller. During the simulation and experimental analysis, it is observed that the FA controller performs well compared to the other individual controllers like hybrid FA-PFL and FA-MGA. The FA-MGA hybrid controller performed well in both static and dynamic systems due to two parametric filters placed in series for path length optimality and navigation time optimality.

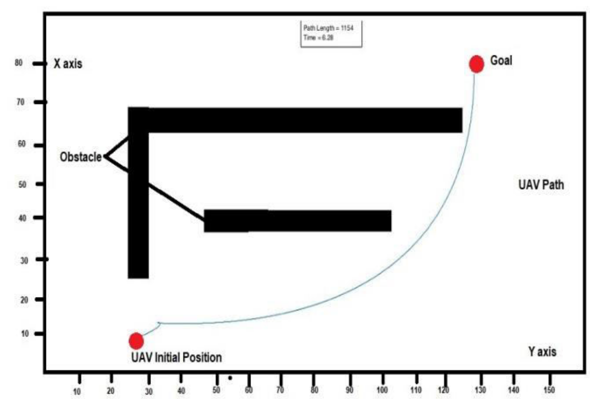

Fig 9 – Navigation using FA – MGA

The proposed multi-copter navigation controller is quite good at avoiding obstacles in the static and dynamic environment. The proposed control avoids accidental movement of the multi-copter in the environment and ensures optimal trajectory planning. Using the FA to hybridize with other controllers gives better results than the FA controller. Hybrid controllers like FA-PFL, FA-MGA are more efficient than single FA controllers. By using the hybrid controller, we can keep the percentage deviation between experimental and simulation results within 5%. Finally, from the results obtained, we can say that the development of the hybrid algorithm is very effective for multi-copter navigation used for obstacle detection, collision avoidance and trajectory planning.

VII.CONCLUSION AND FUTURE DIRECTIONS

The design and development of an unmanned aerial vehicle (multi-copter) with high level cognition, path planning and obstacle detection system for all unsafe environments. The analysis was carried out both computationally and experimentally to validate the parameters and obtain the best results. This chapter summarizes the main contributions of the proposed research work and also indicates additional research work that needs to be carried out in the future.

A. Contribution of project work

An intelligent multi-rotor unmanned aerial vehicle (multi-copter) featuring artificial intelligence with a high-level detection, tracking and obstacle detection system, constructed of an advanced lightweight composite material through the incorporation of carbon fiber, glass and Kevlar. The vehicle structure is fully tested under various conditions for mechanical characterization. This vehicle will be able to have artificial intelligence and perform high-level detection and tracking through the application of various advanced algorithms. The other contribution of the work will be the development and verification of a model-based flight simulation for UAVs and there will be a MATLAB simulation for different artificial intelligence systems. The single-cell design is being developed, which can contribute to the additional buoyancy and also accommodate the auxiliary propulsion. The devices and their ducted design offer low peak losses and improved thrust. The development of laminated metal fibers for the multi-copter's arm provides the unique solution for the high-strength central frame and also reduces the weight. The propulsion system evaluation provides the optimally efficient devices that offer maximum endurance. The Firefly algorithm is introduced for optimal multi-computer path planning. Which can also detect obstacles and avoid collisions.

B.Future Directions

In the proposed work, the developed multi-copter is to be tested in various outdoor environments. The developed multi-copter can be tested for various payloads and power, optimization can be done. The proposed work can be extended to the design and development of solar, charging facilities for multicomputer. The disk type design can also be tested on under water with some modifications. More work on Hybrid Controller can be investigated for better results of navigation system.

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