# Design, Fabrication And Analysis Of Quadrotor

**[1]manikandan Ganesan, [2]k. R. Ishwarya,**
[1,2]Department of ElectroMechanical Engineering,
[1,2]Faculty of Manufacturing, Institute of Technology, Hawassa University, Hawassa, Ethiopia
mani301090@hu.edu.et, ishwarya.raghav@gmail.com,

**Abstract**
This paper aims at the design, fabrication and analysis of a quadrotor. It is a UAV that gets its thrust and lift by adjusting the relative speeds of four engines (motors). There are many notable works done in this section, currently Boeing and Bell are building a Quad Tilt Rotor (QTR) with a huge payload carrying capacity. So building a quadrotor will give an opportunity to study the dynamic behavior, governing control system, and sensor filtering techniques. Here in this paperwork a quadrotor is build out of aluminium with a take-off weight of around 1.6 kg and the model is capable of flying indoor or outdoor with an optimal wind speed. To make a stable flight it is equipped with an accelerometer, gyroscope, magnetometer and a barometer.

To give it a small amount of autonomy it is equipped with Obstacle Avoidance system which uses Infrared and Ultrasonic sensors. It is also equipped with 'Fly Home' technique that will fly the quad to its starting point in case of signal loss from the ground control system. A PI controller is used to control the stability and a Kalman filter to filter the errors bound by vibrations, noise etc. The final model will be tested by making it to fly in the outdoor. This quad can be used for surveillance, collecting test samples from hazardous environment, photography, vehicle traffic monitoring etc. In future, algorithms can be built with this base model using vision system to explore unknown surroundings, navigate full autonomously, target tracking etc.

**KEYWORDS:** Quad Tilt Rotor (QTR), Obstacle Avoidance system (OAS), Kalman Filter, Unmanned Aerial Vehicle (UAV), Inertial Measurement Unit (IMU),

## I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot on board. Its flight is either controlled autonomously by computers in the vehicle, or under the remote control of a navigator, or pilot (in military UAVs called a Combat Systems Officer on UCAVs on the ground or in another vehicle. A Micro Air Vehicle (MAV), or micro aerial vehicle, is a class of UAV that has a size restriction and may be autonomous usually operated from on-board battery[1-4]. Modern craft can be as small as 15 centimeters. The small craft allows remote observation of hazardous environments inaccessible to ground vehicles. MAVs have been built for hobby purposes, such as aerial robotics contests and aerial photography.

Miniature aerial vehicles (MAVs) have attracted major research interest during the last decade[5-9]. Recent advances in low power processors, miniature sensors and control theory have contributed to system miniaturization and creation of new application fields. „Quadrotor‟, a vertical take-off and landing (VTOL) system is considered because of their challenging control problems, symmetrical airframe and their broad field of applications. A mathematical model is developed, with governing control system which processes the data from the sensors and fly the MAV autonomously. [10-12] Simple „Obstacle Avoidance System (OAS)‟ is deployed which ensures the safe operation of the Quadrotor.

This work focuses on the design of a Vertical Take-Off and Landing (VTOL) Miniature Aerial Vehicle (MAV). The proposed structure is a four propeller helicopter called quadrotor[13-16]. Since this model is highly stable and can fly at high altitude, which can be used for forest fire monitoring, aerial surveillance and photography, sample collection and analysis of hazardous environments and to understand and implement the concepts of Kalman filters, IMU, PID controller and Euler - angle methods which are the basic algorithms used in any UAV, aircrafts, missiles etc.

### A. Limitations of The Paper

The main limitation is if one motor fails the total structure loses stability due to unbalanced torque and goes out of control. Weight plays a major factor here, so if weight increases, its flight time decreases. To increase the flight time more battery is needed which further increases the Quadrotor total weight making it further complicated [17-22]. Wireless transmission of data is used which is highly non reliable, if Quadrotor gets out of range it should be programmed to come back to initial home point from where flight is started initially

### B. Applications

Forest poachers monitoring, Forest fire monitoring, Aerial surveillance, Aerial photography, exploring unknown environment, sample collection in hazardous environment like volcanic eruption and so on [23-24].

## II. METHODOLOGY

In this section the working of the Quadrotor is involved. The four propellers are used to actuate the Quadrotor. Depends on the propeller speed variation the movement of Quadrotor is obtained. To fly the Quadrotor need to maintain the four propeller speed as constant with maximum speed. Once its flies the direction will be controlled by the speed variation in the different motor

### A. Block Diagram

The main heart of this Quadrotor is controller (microchip). The orientation of the vehicle is sensed by inertial measurement unit (IMU). It will sent the gyro, X-tilt, Y-tilt to the controller. Depends on the feedback the controller will send the signal to the corresponding motor to balance the Quadrotor. The operator will give the input to the controller by remote transmitter to obtain the Thrust, Pitch, Roll and Yaw motions. Corresponding data is processed by the controller it will generate the PWM signal to control the motor speed[25-27]. The fig 2.1 represents how the control system interacts with the physical system for controlled quad-rotor flight

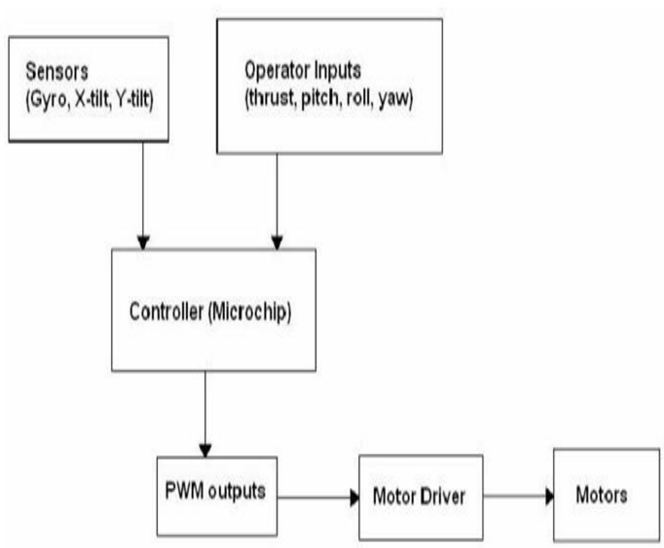


**Fig 2.1 Block Diagram**

### B. Control Flow Chart

The vehicle controls have the particular flow diagram that shown in fig 2.2 To obtain the result the important factor is Design of the Quadrotor in this paper we taken the (+) type design. This design is fully depending upon the application definition. So the Quadrotor mass and size desire the propeller parameter. Depends on the propeller parameter the power requirement is identified. It provides the actuator data base [28-29]. The iterative algorithm used to maintain the stabilization of the vehicle with respect to the variation in the input.

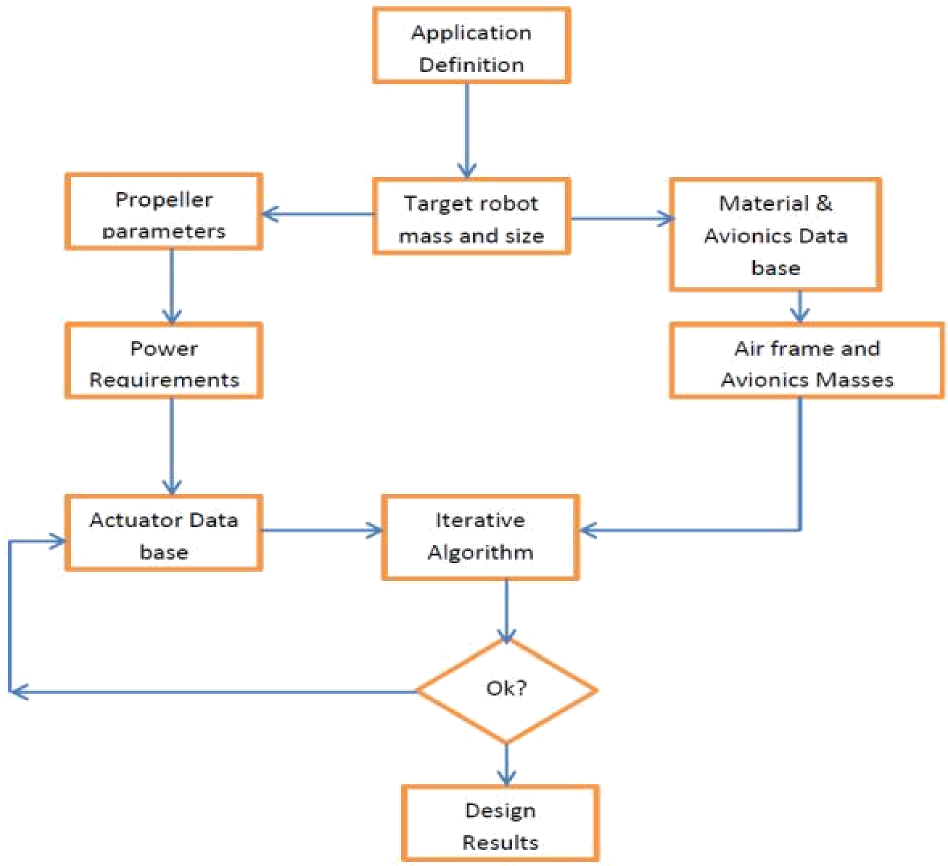


Fig 2.2 Control Flow chart

## III. DESIGN OF QUADROTOR

There are two types of configurations in Quadcopter which is (+) configuration and other is (×) configuration. Due to high stability and easy to control configuration, plus (+) configuration is chosen.

### A. Material Selection of Frame

Due to low weight and high strength Aluminium square tube is chosen as the frame material which is also cheaper when compared to carbon fiber tubes.

### B. Hollow Square Area Calculation

Hollow Square Area $=\text{outer } a^2 - \text{inner } a^2$

$$= [12.7^2 - (12.7-6)^2]*10^{-6}$$

$= 1.164*10^{-4}m^2$

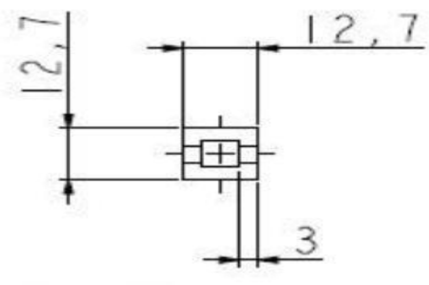


Fig 3.1 . Cross Sectional Area of Arm

**Big arm (1 nos)**

Length = 780mm

=780*10-3 m

Volume = A*h

$=1.164*10^{-4} *780*10^{-3}$

$=9.0792*10^{-5}\ m^3$

Density= Mass/Volume

Density of Aluminium= 2720 kg/m$^3$

Mass = Density* volume

Mass $=2720* 9.0792 * 10^{-5}$

Mass= 0.247 kg

**Small arm(2 nos)**

Length = (780-12.7)/2 =383.63

Length of each tube = $383.63*10^{-3}$ m

Volume = A*h

$= 1.164*10^{-4}*767.3*10^{-3}$

$= 8.931*10^{-5}\ m^3$

Density = 2720 kg/m$^3$

Mass $=2720*8.931*10^{-5}$

Mass = 0.243 kg

Two base Plates, Square in size are used to hold the plus structure together, which has small openings inside to reduce the weight and for also connecting wires from battery. Weights of two base plates are around 0.12 kg

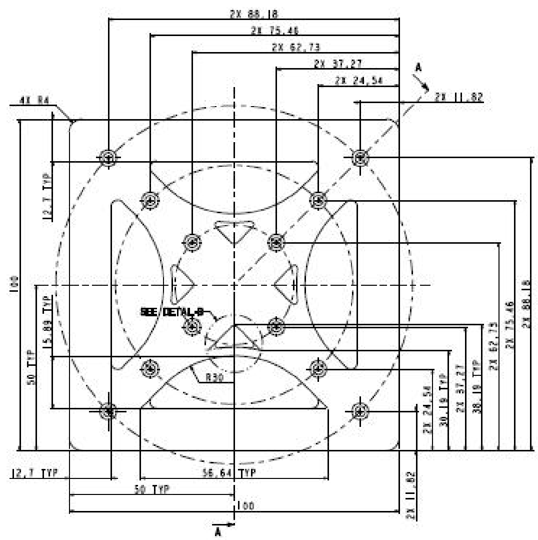


Fig 3.2 Base Plate

**C. Weight Calculation**

The weight of quadrotor is calculated, so that total thrust required can be calculated.

Total weight = Airframe weight + motor weight+ propeller weight + ESC weight+ Battery Weight+ others

=[0.247+0.243+0.12]+ 0.264+0.04+0.160+0.210

AUW= **1.284 kg** (without Flight Controller, wires, Telemetry, Ultrasonic sensors etc.,)

**D. Thrust Calculation**

From weight, we can know how much minimum Thrust we need to have for Stable flight. The thrust is given by

Thrust = AUW * 2

= 1.284 *2

= 2.57 kg ie minimum thrust needed

With 11´´× 4.5´´ Propeller, 800 g of thrust is produced, so

AUW = (4* 800g) [for 4 motors]

AUW=3200 g

At 72% throttle of motor

By increasing motor throttle to 88%, we can increase weight to 4400 g.

**E. 3 D Model of Quadrotor**

Fig 3.3 D Model of Quadrotor

The fig 3.4 shows the 3D model of the quadrotor. It having the (+) configuration frame to hold the motor. The BLDC motor are fixed on the end of the square hallow frame. The thrusters are fixed with motor. The flight controller module placed top side on centre of the frame. The battery fixed bottom side in the centre of the frame.


Fig 4.1 Brushless DC Motor

## IV HARDWARE DESIGN

### A. BLDC Motor

The motors are brushless, DC motors rated for 11 V, 18 amps is shown in Figure 4.1. The DC, brushless Motor configuration was desired for ease of control (ability to control via PWM). The motors use strong rare earth magnets and provide the best power to weight ratio of the hobby motors available for model aircraft.

The motors used are limited to hobby motors due to design budget. As a result, the rest of the structural design revolves around these motors and the allowable weight of the craft based on the lift provided by these motors.

B. **Electronic Speed Control**

An electronic speed control or ESC shown in Figure 4.2. It is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake.

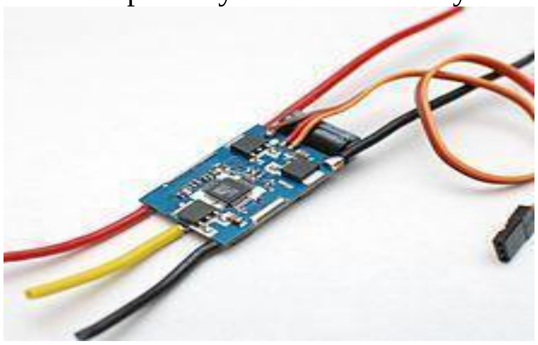

Fig 4.2 Electronic Speed Control

ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three phase electric power low voltage source of energy for the motor[38-39].

C. **Propellers**

The propellers are 11” from tip to tip. Two are of the tractor style, for clockwise rotation, and the other two are of the pusher style, for counter clockwise rotation. For our design, a propeller with a shallow angle of attack as shown in Figure above was necessary as it provides the vertical lift for stable hovering. The propellers used here is steeper than the ideal design because of limited availability of propellers that are produced in both the Tractor and Pusher styles.

D. **Flight Controller**

A Flight controller shown in Figure above is an electronic circuit board has sensors, microcontrollers, interfacing units that fly the Quadcopter by getting values from sensors and computing them. The selected controller has accelerometer, gyroscope and a ATMEGA 8 bit processor. Its shown in Fig 4.3

Fig 4.3 Flight Controller

E. **Radio Transmitter/Receiver**

Radio signal is used to control the Quadrotor from the ground. The RC model we opted is FLYSKY with 6 channels but 4 channels would be enough[33-37]. This is shown in Figure 4.4. This transmitter used to send the command from the user to controller.

Fig 4.4 Radio Transmitter and Receiver

F. **Wires**

As the motors can use current up to 25A, there is need for special wires that can handle high current without failure. Normal wires fail due to overheating. So special wires like Silicone wires are used, which can withstand $200^{o}$ C and also they are very Flexible so that they can be bent and used.

G. **Connectors**

Since we are dealing with current around 80A, it is mandatory to use special connectors that can withstand high current. Motors use Bullet connectors, battery use Deans T connector; we can also use XT60 Nylon made connector which is easy to handle.

## V. CONTROLLER DESIGN

Two PI loops are used independently to control Pitch, Roll and Yaw. Since Pitch and Roll are same here due to symmetry structure one PI loop for controlling this and other for Yaw movement. This PI values are tuned accordingly to reduce/increase the settling Time.

### A. Digital Filter Design

To get error free value from the sensors, there is need for Filters which identifies noise and eliminates them. Kalman Filter would be the filter of priority but due to its complexity and need of huge processing power, we just adopt Complementary Filter which just averages the value from the accelerometer and gyroscope at some rate called Timing constants. This constant defines how for the weightage given to each sensor. Accelerometer drifts initially, as time passes it works fine. On the other case Gyroscope works fine in a short run as it measure only rate of change. So accelerometer can be trusted here. So we have timing constant so that accelerometer value has more weightage than gyroscope

Filtered gyro = A * filtered gyro + (1-A)*gyro rate

Filtered acc = A * filtered acc + (1-A)*acc angle

Filtered angle = $\theta$ * filtered gyro + filtered acc

Where $\theta$ = A / (1-A) * dt

dt - loop time

A - constant

$\theta$ -Timing constant

### B. Auto Stabilization

To fly stable, there is need to keep the platform horizontal always. To stabilize we use sensors to measure the tilt in the platform and compensating them by adjusting the motor speed.A 3-axis Accelerometer, 2-axis gyroscope and a 1-axis gyroscope is used. Z-axis yaw is measured with the single axis gyroscope as Z-axis drifts very easily.fig 5.1 shows block diagram of auto stabilization

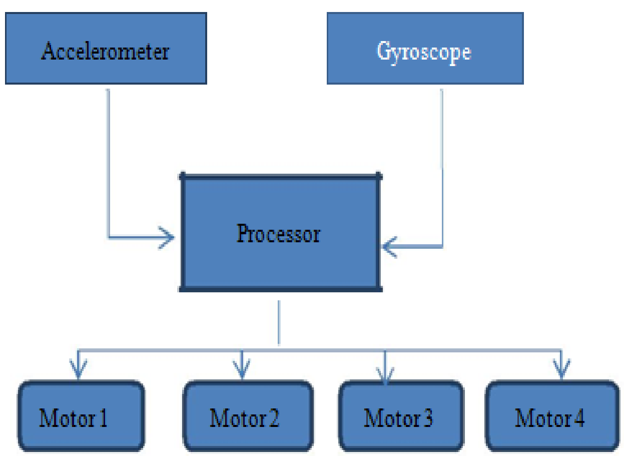


Fig 5.1 Auto Stabilization

## VI. CONCLUSION AND RESULT

This paper proposes Design, Fabrication and Analysis of Quadrotor UAV. A final test has been done by flying the model and its behavior is analyzed and accordingly some parameters are adjusted. This UAV is designed for working in extra-terrestrial applications and aerial photography. The final Designed and tested

Quadrotor is shown in fig 6.1

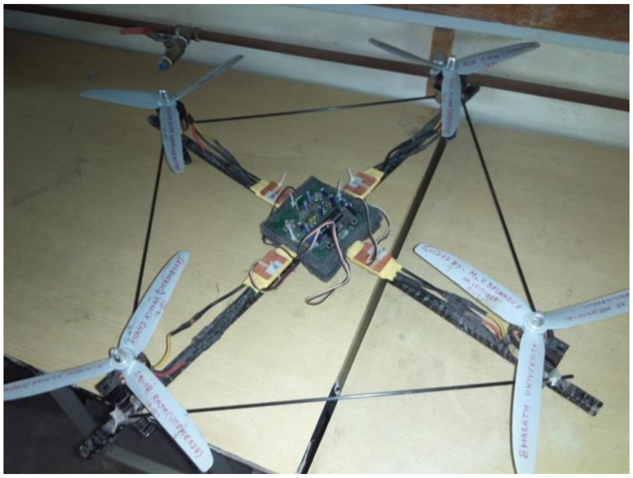

Fig 6.1 final Designed and tested Quadrotor

## REFERENCES

1. Adrupilot (2012) http://www.DIYdrones.com

2. Babu T.A., Sharmila V., "Cefotaxime-induced near-fatal anaphylaxis in a neonate: A case report and review of literature", Indian Journal of Pharmacology, ISSN : 0253-7613, 43(5) (2011) pp.611-612.

3. Ascending Technologies, www.asctec.de

4. Valiathan G.M., Thenumgal S.J., Jayaraman B., Palaniyandi A., Ramkumar H., Jayakumar K., Bhaskaran S., Ramanathan A., "Common docking domain mutation e322k of the erk2 gene is infrequent in oral squamous cell carcinomas", Asian Pacific Journal of Cancer Prevention, ISSN : 1513-7368, 13(12) (2012) pp.6155-6157.

5. Bouabdallah S, Siegwart R (2007) "Full control of a quadrotor". In: Proceedings of theIEEE international conference on intelligent robots, 2007, pp 153-158

6. Mani Sundar N., Krishnan V., Krishnaraj S., Hemalatha V.T., Alam M.N., 'Comparison of the salivary and the serum nitric oxide levels in chronic and aggressive periodontitis: A biochemical study", Journal of Clinical and Diagnostic Research, ISSN : 0973 - 709X, 7(6) (2013) pp.1223-1227.

7. Bouabdallah .S, Siegwart .R (2007),"Design and Control of a Miniature Quadrotor*",* Intelligent systems, control, and automation: science and engineering, volume 33, ISBN 978-1-4020-6113-4, pp 171-210.

8. Dhanasekar J, Manikandan G and Sridevi S, Bluetooth Control Robot with Position Monitoring System, International Journal of Innovative Research in Science, Engineering and Technology, (ISSN(Online): 2319 – 8753& ISSN (Print) :2347 – 6710) Vol. 4, Issue 9, September 2015,Page no. 8373-8378.

9. Carlo Canetta et al. (2007), "Quad-rotor Unmanned Aerial Vehicle", Columbia University.

10. Manikandan G, Sridevi S and Dhanasekar J, Vision based Autonomous Underwater Vehicle for Pipeline Tracking, International Journal of Innovative Research in Science, Engineering and Technology,( ISSN(Online): 2319 – 8753& ISSN (Print) :2347 – 6710) Vol. 4, Issue 1, January 2015,Page no. 18480-18488

11. Subbaraj G.K., Kulanthaivel L., Rajendran R., Veerabathiran R., "Ethanolic extract of Carum carvi (EECC) prevents N-nitrosodiethylamine induced phenobarbital promoted hepatocarcinogenesis by modulating antioxidant enzymes", International Journal of Pharmacy and Pharmaceutical Sciences, ISSN : 0975 - 1491, 5(S1) (2013) pp.195-199.

12. McKerrow P (2004), "Modeling the draganflyer four-rotor helicopter". In: Proceedings of the IEEE international conference on robotics and automation,Vol.4, pp 3596 – 3601.

13. Nanomi K et al. (2009), "Autonomous Control of a Mini Quadrotor Vehicle Using LQG Controllers", Autonomous Flying Robots, ISBN 978-4-431-53855-4. pp 61-76.

14. Nanomi K et al. (2009), "Autonomous Indoor Flight and PreciseAutomated-Landing Using Infrared and Ultrasonic Sensors", Autonomous Flying Robots, ISBN 978-4-431-53855-4. pp 303-322.

15. Thanh Mung Lam (2009), "Design, Implement and Testing of a Rotorcraft UAV System", Aerial vehicles, ISBN 978-953-7619-41-1, pp 537-554.

16. [Ganesh Babu Loganathan, Praveen M., Jamuna Rani D., "Intelligent classification technique for breast cancer classification using digital image processing approach" IEEE Xplore Digital Library 2019, Pp.1-6.

17. Dr.Idris Hadi Salih, Ganesh Babu Loganathan, "Induction motor fault monitoring and fault classification using deep learning probablistic neural network" Solid State Technology(2020), Volume 63, Issue 6, PP No. 2196-2213.

18. Ganesh Babu Loganathan, "Design and analysis of high gain Re Boost-Luo converter for high power DC application", Materials Today: Proceedings(2020), Volume 33, Part 1, PP 13-22.

19. M. Viswanathan, Ganesh Babu Loganathan, *and* S. Srinivasan, “IKP based biometric authentication using artificial neural network”, AIP Conference Proceedings (2020), Volume 2271, Issue 1, pp 030030.

20. Mohammed Abdulghani Taha and Ganesh Babu Loganathan, “Hybrid algorithms for spectral noise removal in hyper spectral images” AIP Conference Proceedings (2020), Volume 2271, Issue 1, pp 030013.

21. Ganesh Babu Loganathan, “Vanet Based Secured Accident Prevention System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.06, P.No. 285-291.

22. Ganesh Babu Loganathan, “Can Based Automated Vehicle Security System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.07, P.No. 46-51.

23. G Sharma, A Rajesh, L Ganesh Babu, E Mohan, “Three-Dimensional Localization in Anisotropic Wireless Sensor Networks Using Fuzzy Logic System”, Adhoc & Sensor Wireless Networks, (2019) Vol.45 Issue No.1, P.No. 29-57.

24. Ganesh Babu Loganathan, Dr.E.Mohan, R.Siva Kumar, “ Iot Based Water And Soil Quality Monitoring System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.2, P.No. 537-541.

25. Suganthi K, Idris Hadi Salih, Ganesh Babu Loganathan, and Sundararaman K, “A Single Switch Bipolar Triple Output Converter with Fuzzy Control”, International Journal of Advanced Science and Technology, (2020), Vol. 29, No. 5, (2020), P.No.. 2386 – 2400.

26. B.K. Patle, Ganesh Babu L, Anish Pandey, D.R.K. Parhi, A. Jagadeesh,A review: On path planning strategies for navigation of mobile robot, Defence Technology, Volume 15, Issue 4, August 2019, Pages 582-606.

27. Dr.A.Senthil Kumar, Dr.Venmathi A R ,L.Ganesh Babu, Dr.G. Suresh, “Smart Agriculture Robo With Leaf Diseases Detection Using IOT”, European Journal of Molecular & Clinical Medicine, Volume 07, Issue 09, PP 2462-2469.

28. Ganesh Babu L 2019 Influence of benzoyl chloride treatment on the tribological characteristics of Cyperus pangorei fibers based nonasbestos brake friction composites Mater. Res. Express 7 015303.

29. Manoharan S, Sai Krishnan G, Babu L G, Vijay R and Singaravelu D L 2019 Synergistic effect of red mud-iron sulfide particles on faderecovery characteristics of non-asbestos organic brake friction composites Mater. Res. Express 6 105311.

30. Manoharan S, Shihab A I, Alemdar A S A, Ganesh Babu L, Vijay R and Lenin Singaravelu D 2019 Influence of recycled basalt-aramid fibres integration on the mechanical and thermal properties of brake friction composites Material Research Express 6 115310.

31. G Sai Krishnan , L Ganesh Babu, P Kumaran , G Yoganjaneyulu and Jeganmohan Sudhan Raj, “Investigation of Caryota urens fibers on physical, chemical, mechanical and tribological properties for brake pad applications”, Material Research Express 7 015310

32. A.Devaraju, P.Sivasamy, Ganesh BabuLoganathan, “Mechanical properties of polymer composites with ZnO nano-particle” , Materials Today: Proceedings(2020), Volume 22, Part 3, Pages 531-534

33. Qaysar S.Mahdi, “Prediction of Mobile Radio Wave Propagation in Complex Topography” , Eurasian Journal of Science & Engineering, Volume 4, Issue 1 (Special Issue); September, 2018, PP 49-55.

34. Qaysar S. Mahd, “Survivability Analysis of GSM Network Systems”, Eurasian Journal of Science & Engineering, Volume 3, Issue 3;June, 2018, PP 113-123.

35. Qaysar S.Mahdi, “Comparison Study of Multi-Beams Radar under Different Radar Cross Section and Different Transmitting Frequency”, Eurasian Journal of Science & Engineering, Volume 3, Issue 3; June, 2018, PP 1-11.

36. Qaysar Salih Mahdi, Idris Hadi Saleh, Ghani Hashim, Ganesh Babu Loganathan, “Evaluation of Robot Professor Technology in Teaching and Business”, Information Technology in Industry, Volume 09, Issue 01, PP 1182-1194.

37. Mr.Manikandan Ganesan, Mrs.Ishwarya K. R, Mr. Demoz Lisanework, Mr.Ayenachew Hailu Mengiste, “Investigation On Autonomous Pesticide Spraying Robotic Vehicle In Agriculture Field”, International Journal of Modern Agriculture, Volume 10, No.1, 2021 pp 382-386.

38. Ellappan Mohan, Arunachalam Rajesh , Gurram Sunitha , Reddy Madhavi Konduru , Janagaraj Avanija, Loganathan Ganesh Babu, “A deep neural network learning-based speckle noise removal technique for enhancing the quality of synthetic-aperture radar images”, Concurrency And Computation-Practice & Experience, https://doi.org/10.1002/cpe.6239.

39. Dr.A.Senthil Kumar, Dr.G.Suresh, Dr.S.Lekashri, Mr.L.Ganesh Babu, Dr. R.Manikandan, “Smart Agriculture System With E – Carbage Using Iot”, International Journal of Modern Agriculture, Volume 10, No.1, 2021 pp 928-931.