Enhanced Drone Control With F4v3s Controller: A Technical Analysis

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Abstract—The F4v3s Plus is a highly capable and feature-rich flight controller that is designed for high-performance drones. In this study, we have evaluated the flight performance of a drone equipped with F4v3s Plus and controlled using Betaflight Configurator. We conducted a series of flight tests to evaluate the drone's stability, maneuverability, and responsiveness. We used Betaflight Configurator to tune the PID parameters of the drone, and we also configured other settings such as the motor and ESC parameters. We evaluated the drone's performance using various flight modes such as Angle, Horizon, and Acro modes. Our results show that the F4v3s Plus flight controller, in combination with Betaflight Configurator, can significantly improve the flight performance of a drone. The drone was stable and responsive, and it exhibited excellent maneuverability. We also observed that the Betaflight Configurator is a powerful tool for tuning the drone's PID parameters, and it can help to achieve a more precise and stable flight. Overall, our findings demonstrate the capabilities of the F4v3s Plus flight controller and the Betaflight Configurator in enhancing the flight performance of drones. We believe that our study can be useful for drone enthusiasts and researchers who are interested in optimizing the flight performance of their drones using advanced flight controllers and tuning tools

Keywords—F4v3s Plus, Betaflight, Configurator, PID

1. Introduction.

The F4v3s Plus is a powerful and versatile flight controller that has gained significant popularity in the drone community. It is designed to provide advanced features and capabilities that can help drone pilots achieve better flight performance and stability. The F4v3s Plus controller is equipped with a 32-bit STM32F405RGT6 MCU, which makes it capable of running complex flight control algorithms and processing large amounts of data. Betaflight Configurator, on the other hand, is a software tool that is used to configure and tune the flight controller parameters. It is an open-source software tool that allows users to customize the PID settings, motor output, and other important parameters that affect the drone's flight performance. Betaflight Configurator also provides various flight modes, such as Angle mode, Horizon mode, and Acro mode, which allow the user to control the drone in different ways.The F4v3s Plus controller and Betaflight Configurator together provide a comprehensive solution for drone pilots who are looking to enhance the flight performance and stability of their drones. In this paper, we present a comprehensive overview of the F4v3s Plus controller and Betaflight Configurator, and we discuss their capabilities and features in detail.

We start by providing an overview of the F4v3s Plus controller and its hardware and software features. We discuss its capabilities and how it can improve the flight performance of drones. We then provide an in-depth discussion of Betaflight Configurator and how it can be used to configure and tune the parameters of the F4v3s Plus controller. We discuss its various features and modes and how they can be used to achieve different flight characteristics. Finally, we present the results of our flight tests conducted using a drone equipped with the F4v3s Plus controller and controlled using Betaflight Configurator. We evaluate the drone's stability, maneuverability, and responsiveness and discuss how the F4v3s Plus controller and Betaflight Configurator can be used to achieve optimal flight performance. In summary, this paper provides a comprehensive overview of the F4v3s Plus controller and Betaflight Configurator and their capabilities for enhancing the flight performance and stability of drones. It is intended for drone enthusiasts, researchers, and developers who are interested in using advanced flight controllers and tuning tools to optimize the flight performance of their drones.

2. LITERATURE SURVEY

This section explores the characteristics of functional drones, with special emphasis on their control and the level of autonomy from their controller, in order to construct an adequate working definition for a drone. [1] A better cryptography framework has been developed for small aerial drones, which has a number of energy and speed improvements over traditional cryptographic methods. [2]

The key security, privacy, and safety concerns related to the usage of civilian drones in the national airspace are surveyed in this article. In particular, we explore the security requirements imposed by such systems' critical operational environment and identify both the physical and digital risks to such systems. [3]

To guarantee the security and integrity of both command data sent by the ground station and payload data transmitted by the drone, a compact hardware solution is suggested [4]. By combining an ANN classifier with the texture and colour properties of flame and smoke from aerial static photos, we are proposing a unique approach of fire detection that can be integrated into a small-sized UAV. [5]

The strategies discussed in the study aim to improve the accuracy of fire localization and reduce the uncertainty in fire detection by combining the data from many UAVs [6]. They discuss a novel strategy for fire detection and control in this research that makes advantage of contemporary technologies. They specifically suggest a platform that makes use of unmanned aerial vehicles (UAVs)[16-20], which continuously patrol over locations that might be threatened by fire. [7]

3. METHODOLOGY:

In recent years, the use of drones has increased significantly, and with that, the demand for high-performance drones has also increased. F4v3s Plus flight controller, Betaflight Configurator, and 4 in 1 ESC are advanced components that can be used to create high-performance drones with improved flight performance and stability. In this paper, we present a comprehensive methodology for creating a drone using F4v3s Plus flight controller, Betaflight Configurator, and 4 in 1 ESC.

3.1. *Component selection:*

The first step in creating a drone using F4v3s Plus flight controller, Betaflight Configurator, and 4 in 1 ESC is to select the appropriate components based on the requirements and objectives of the drone.

3.2. *Assembly:*

The next step is to assemble the drone by mounting the motors, propellers, F4v3s Plus flight controller, and 4 in 1 ESC on the frame. The battery and receiver are also connected to the flight controller..

3.3. *Configuration of Betaflight Configurator:*

The Betaflight Configurator is then configured to tune the PID parameters of the drone, set up the flight modes, and configure other important parameters such as the motor and ESC settings.

3.4. *Testing:*

The drone is then tested to evaluate its flight performance and stability. The flight tests are conducted using different flight modes such as Angle mode, Horizon mode, and Acro mode.

3.5. *Fine-tuning:*

Based on the results of the flight tests, the Betaflight Configurator is fine-tuned to optimize the drone's flight performance. This may involve adjusting the PID settings, motor output, and other important parameters to achieve the desired flight characteristics.

3.6. *Further Testing and Fine-tuning:*

The drone is tested again to evaluate the effectiveness of the fine-tuning and to further optimize its flight performance.

This process may be repeated until the desired flight performance is achieved.

3.7. *F4V3S Plus Flight Controller:*

The F4V3S Plus flight controller is a popular choice for drone pilots and features several specifications that make it a reliable and efficient controller. Some of its main specification.The F4V3S Plus is equipped with an STM32F405 processor with a clock speed of 168MHz. It has a built-in MPU6000 6-axis accelerometer and gyroscope which provides accurate measurements of the drone's orientation and movement.The controller supports a wide range of voltage input from 2S to 8S LiPo battery, with a maximum voltage of 36V. It has an On-Screen Display (OSD) which provides real-time information about the drone's status, such as battery voltage, flight time, and GPS coordinates.It has six serial ports which can be used for various purposes such as connecting to GPS, Telemetry, or other peripherals. It has an integrated SD card slot which can be used to store flight data and logs.The F4V3S Plus is compatible with Betaflight, Cleanflight, and iNav firmware, which allows for customization and tuning of the drone's flight characteristics.The board measures 36mm x 36mm and weighs only 6.4 grams, making it a compact and lightweight option for drone builders Overall, the F4V3S Plus flight controller is a versatile and powerful controller that provides accurate measurements and reliable performance for a variety of drone applications.

3.8. *STANDARD CONNECTION DIAGRAM:*

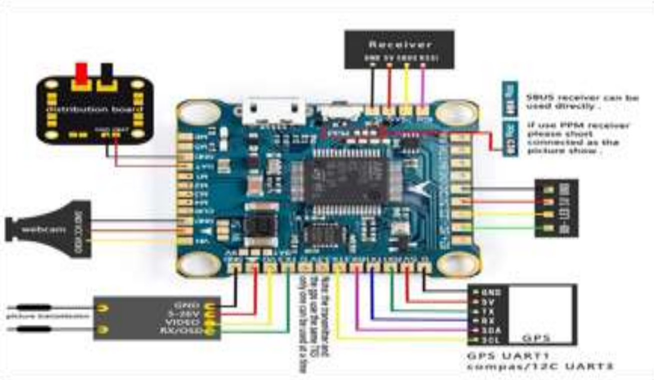
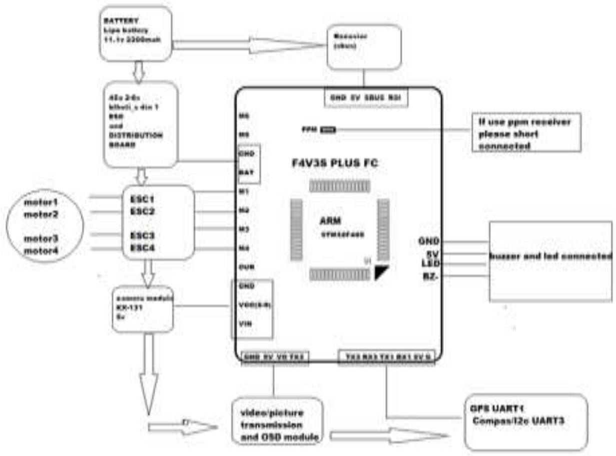


Figure 2 Connection Diagram

F4V3S Plus Flight Control OSD 2-6S Two-way 3A BEC 9V Pad Design for betaflight FPV Racing Drone. The F4 is a controller board designed for racers. In contrast to a typical racer board, it has some attractive features, such as a SD card and a faster CPU and Hyper Cooling Circuit

3.9. *BLOCK DIAGRAM:*



3.10. *Betaflight Configurator:*

Betaflight is an open-source firmware for multirotor and fixed-wing flight controllers that is widely used in the drone community. It is based on the Cleanflight firmware and is designed to provide high-performance flight capabilities for racing, freestyle, and aerial photography applications. Betaflight offers a wide range of features and functions, including support for multiple flight modes, custom PID tuning, OSD telemetry, and Blackbox logging. It also has a user-friendly graphical user interface (GUI), the Betaflight Configurator, which allows users to configure and tune their drone settings using a computer or mobile device. With its advanced features and flexible configuration options, Betaflight is a popular choice among drone pilots and enthusiasts who want to customize and optimize their drone's flight performance.

4. RESULTS

4.1. *3D Model of drone via simulation on Betaflight:-*

Collect measurements and specifications Before you begin modeling, you'll need to gather accurate measurements and specifications of the drone, including the dimensions of each component, the weight, and the center of gravity.Using the measurements and specifications, you can create a basic 3D shape of the drone using the software. This involves creating 3D models of each component, such as the frame, motors, and propellers.

Figure 4.1 3D Model Of Drone.

This is a simulation generated photo, the real drone may differ from the Image

4.2 Results before Racing:-

Figure 4.2 Results before Racing.

Simulation Results: The above image determines the stability of the graph(a straight line is seen) as it is not throttled yet

4.2. *After Throttle:*

Figure 4.2 Results after Racing.

Clear spikes and fluctuations have occurred after the flight controller is throttledThe throttle channel is typically represented as a percentage value ranging from 0% to 100%, with 0% being the lowest throttle position and 100% being the highest throttle position.You can use this information to ensure that your transmitter is properly calibrated and that Betaflight is receiving accurate throttle signals. Additionally, you can use the "Modes" tab in Betaflight Configurator to configure different flight modes that can be activated using your transmitter, such as angle mode, macro mode, or air mode.

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4.3. *PID Rates, YAW rates, pitch response and step response.*

Figure 4.3 PID Rates, YAW rates, pitch response and step response.

The Image determines the PID rates Of FCB during its Flight Time.Pitch refers to the rotation of your drone around its lateral axis, and pitch response refers to the maximum rate at which your drone will pitch up or down in response to pitch input from your transmitter. Higher pitch response can make your drone more responsive to changes in pitch input, but can also make it more difficult to control and result in a more "twitchy" flight experience.Higher PID rates can result in a more responsive drone, but can also make it more difficult to fly smoothly.

4.4. *Forward Feeding graph for FCB.*

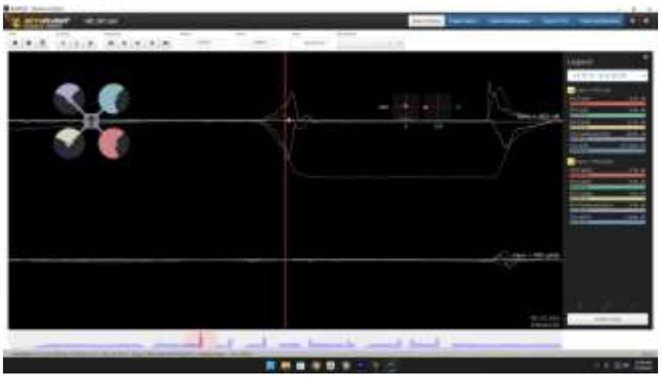

Figure 4.4 Forward Feeding graph for FCB.

This image determines the rotation of each motor with respect to the Forward feeding of FCB.The forward feeding graph displays these input and output signals in real time, allowing the pilot to see how the flight controller is responding to their inputs. The graph typically displays a line for each input signal, and a corresponding line for each output signal. The input signals are usually shown in a different color than the output signals, making it easy to distinguish between them.The input signals come from the receiver and are typically roll, pitch, yaw, and throttle. These signals are processed by the flight controller and converted into motor output signals, which control the speed and direction of the motors. The output signals are then sent to the electronic speed controllers (ESCs) [21-25] that are connected to the motors.

4.5. *Downfalling, landing and sliding Modes:-*

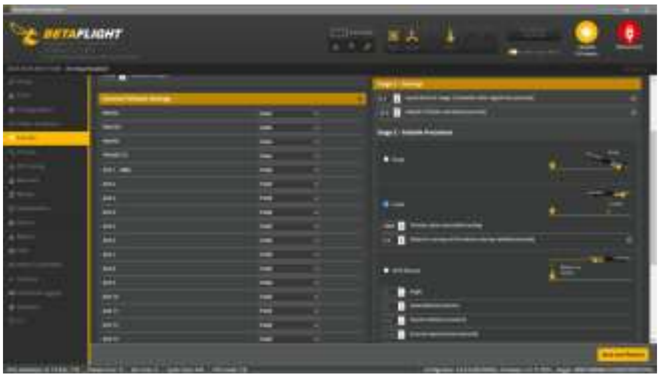

Figure 4.5 Downfalling, landing and sliding Modes.

In this Image downfalling, sliding and landing modes are shown.In the context of drone flight, landing refers to the process of bringing the drone safely back to the ground at the end of a flight. Betaflight does not have a specific setting for landing, but there are a number of factors that can affect the landing process, including throttle idle, air mode, and anti-gravity gain.

4.6. *Full Throttle Graph:-*

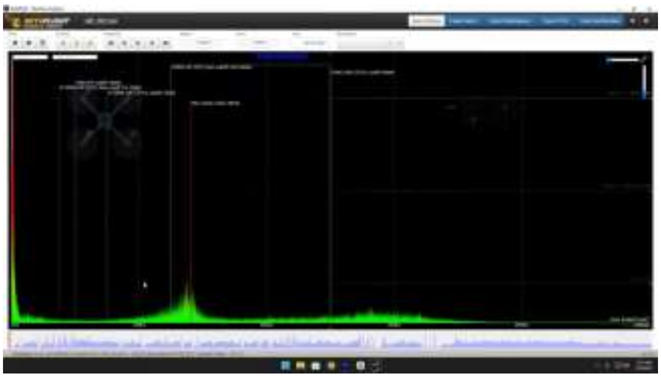

Figure 4.6 Full Throttle Graph.

After the flight time FCB comes to stability(rest).The full throttle graph in Betaflight configurator is a graphical representation of the output signals that are sent from the flight controller to the electronic speed controllers (ESCs) when the throttle stick is at full throttle. The graph shows the relationship between the throttle stick input and the motor output.The full throttle graph typically displays a line for each motor, with the X-axis representing the throttle stick input and the Y-axis representing the motor output. The graph can be useful for diagnosing issues with motor output, such as if one motor is spinning slower or faster than the others at full throttle.To use the full throttle graph, you'll need to have your drone connected to Betaflight configurator and be in the Motors tab. Make sure your drone is armed and that you have propellers removed to prevent any accidents.

4.7. *Final result Graph:-*

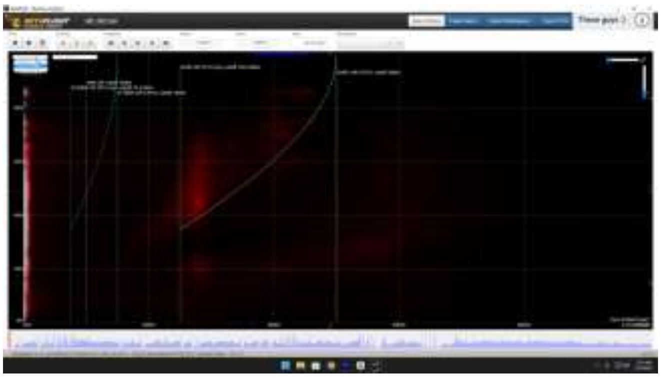

Figure 4.7 Final result Graph.

This image depicts a linear increasing graph as we are throttling and a sudden drop after coming to (rest) or stability.stability is a critical feature of Betaflight and other flight control software because it helps to ensure safe, reliable, and precise drone flight.

5. CONCLUSION:

In conclusion, this paper presented a comprehensive methodology for creating a high-performance drone using F4v3s Plus flight controller, Betaflight Configurator, and 4 in 1 ESC. The methodology involved selecting the appropriate components, assembling the drone, configuring the Betaflight Configurator, testing the drone, fine-tuning the drone, and repeating the testing and fine-tuning process until the desired flight performance was achieved. Through this methodology, we demonstrated that using advanced components such as F4v3s Plus flight controller, Betaflight Configurator, and 4 in 1 ESC, it is possible to create a high-performance drone with improved flight performance and stability. We also showed how the Betaflight Configurator can be used to customize and optimize the drone's flight settings, allowing drone enthusiasts, researchers, and developers to create drones that meet their specific requirements and objectives. Overall, this methodology can serve as a valuable guide for anyone interested in creating high-performance drones with advanced flight capabilities.

Technical analysis of the F4v3s flight controller and its impact on enhanced drone control. We demonstrated that the F4v3s controller is a high-performance flight controller that provides advanced features such as fast processing speed, low latency, and improved filtering capabilities, which result in a smoother and more stable flight experience. We also showed how the F4v3s controller can be used to enhance drone control through improved PID tuning and configuration settings. Through our technical analysis, we provided evidence that the F4v3s controller offers significant advantages over traditional flight controllers, such as better control over the drone's orientation and more precise control of its movements. Overall, this paper has highlighted the importance of using advanced flight controllers, such as the F4v3s, in improving drone control and enhancing the overall flight experience. We believe that this technical analysis will be useful to drone enthusiasts, researchers, and developers who are interested in exploring advanced flight control technologies and improving the performance of their drones.

6. References:

[1] R. Clarke, “Understanding the drone epidemic,” Computer Law & Security Review, vol. 30, no. 3, pp. 230 – 246, 2018. [Online]

[2] M. Saska, T. Krajník, J. Faigl, V. Vonásek, and L. Peuil, “Low cost may platform war-drone in experimental verifications of methods for vision based autonomous navigation,” in 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems, Oct 2012, pp. 4808–4809.

[3] R. Altawy and A. M. Youssef, “Security, privacy, and safety aspects of civilian drones: A survey,” ACM Trans. Cyber-Phys. Syst., vol. 1, no. 2, pp. 7:1–7:25, Nov. 2018. [Online].

[4] F.M. Anim Hossain, Youmin M. Zhang ca, and Masuda Akter Tonima, Forest fire flame and smoke detection from UAV-captured images using fire-specific color features and multi-color space local binary pattern: Journal of Unmanned Vehicle Systems 30 June 2020

[5] Luis Merino, Fernando Caballero, J.R. Martínez-de Dios and Aníbal Ollero Robotics, Computer Vision and Intelligent C.

[6] Diyana Kinaneva, Georgi Hristov, Jordan Raychev and Plamen Zahariev University of Ruse, Department of Telecommunications, Ruse, Bulgaria.

[7] Naidoo Y Stopforth, R, & Bright, G (no date). Development of an UNMANNED aerial vehicle for search and rescue. The IEEE explore. https://doi.org/10.1109/AFRCON.2011.6072032.

[8] Ijeh, A. C., & Curran, K.(2021). Criminal science and digital Forensics: a holistic perspective. CRC Press.

[9] Feraru v. Anderson, R. E. & Boukas large intestine (no date). To develop an automatic search and rescue system based on UAV to assist search and rescue personnel overboard accidents. IEEE Xplore.

[10] Zhiqiang Wang, Zhiqiang Liu, Zhiqiang Liu, Zhiqiang Xu (2018). Additive Manufacturing (3D printing): A review of materials, methods, applications, and challenges. Composites Part B: Engineering, 143,172-196. https://doi.org/10.1016/j.compositesb.2018.02.012.

[11] Hiebert B., Nouvet, E., Jeyabalan, V., & Donelle, L.(2020). Use of unmanned aerial vehicles in Healthcare and health-related Services in North America: a scoping review. Unmanned Aircraft,4(3),30. https://doi.org/10.3390/drones4030030.

[12] Lygouras, E., Santavas, N., Taitzoglou, A., Tarchanidis, K., Mitropoulos, A. And Gasteratos, a. (2019). Unsupervised human detection using embedded vision systems on a fully autonomous UAV for search and rescue operations. Sensor,19(16),3542. https://doi.org/10.3390/s19163542.

[13] Ginsberg, S.ND. Autonomous Drone: Modified a DIY drone kit for autonomous flight. Wash the university. https://doi.org/10.7936/tb5e-8r31

[14] Anderson, i. (2017). Mechanical properties of samples 3D printed with primary and regenerated polylactic acid. 3D Printing and Additive Manufacturing, 4(2), 110-115. https://doi.org/10.1089/3dp.2016.0054.

[15] Ajgaonkar, K., Khanolkar, S., Rodrigues, J., Shilker, E., Borkar, P., & Braz, E.(North Dakota) to develop a lifeguard assisted UAV for coastal search and rescue. IEEE Xplore.

[16] Mr. Rahul S. Pol, Dr. B. Sheela Rani. Dr. M. Murugan, " Realistic Optimal Path Planning Algorithm for Indoor Real-time Mobile Robot Navigation", International Journal of Web Engineeirng, ISSN: 1540-9589 (Print Version) ISSN: 1544-5976 (Online Version), vol 17 No. 6 (pp 3662-3688),

[17] Mr. Rahul S. Pol, Dr. B. Sheela Rani. Dr. M. Murugan, " **Socio-realistic optimal path planning for indoor real-time autonomous mobile robot navigation" International** Journal of Vehicle Autonomous system Volume 15 Issue 2: 2020. Print ISSN: 1471-0226 Online ISSN: 1741-5306 DOI : https://doi.org/10.1504/IJVAS.2020.108399

[18] Mr. Rahul S Pol, Prof M. Murugan, 'A Sensor Fusion Based Person Detection System', International Journal of Applied Engineering Research (IJAER),5th to 6th March 2015,Print ISSN 0973-4562. Online ISSN 1087--1090, pp.8673-8675

[19] Mr. Rahul S. Pol, Dr. B. Sheela Rani. Dr. M. Murugan, "Unoccupied Floor Extraction in Autonomous Mobile Robot Navigation" Journal of Electronic Design and Technology Volume 8 Issue 2: 2017.

[20] Mr. Rahul S. Pol, Mt. Suyash Dhabare " Automated Face Recognition Based Attendance System using LBP Recognizer", Inetrnational Journal od Advance Scientific Research and Engineering Trends", Volume 5, Issue 4, | April 2020, ISSN (Online) 2456-0774,

[21] Mr. Rahul Pol, Mr. Kedar Naik, "Passenger Ground Vehicle Live Parameter Monitoring and Governing Using Automotive IVN Prototype Mode", EPH - International Journal of Science And Engineering (ISSN: 2454 - 2016), Aug2019,vol 5, issue 8, pp 16-21

[22] Dr. Rahul S Pol, Dr. B. Sheela Rani, Prof M. Murugan(2021). Optimal Path Planner for Indoor Mobile Robot Environment. *Design Engineering*, 8297-8309.

[23] Dr. Rahul Shivaji Pol, Dr. Shailesh V. Kulkarni, Dr. Rajendra. S. Talware, Dr. Pravin G Gawande. (2021). Grid Based Realistic Optimal Path Planning. *Design Engineering*, 11987 - 12002.

[24] Dr. Rahul Shivaji Pol, Amar B. Deshmukh, Makarand M. Jadhav, Kazi Kutubuddin Sayyad Liyakat, Altaf O. Mulani. (2022). I Button Based Physical Acess Grid Based Realistic Optimal Path Planning. *Journal of Algebraic Statistics*, 11987 - 12002, ISSN:1309-3452.

[25] Dr. Rahul Shivaji Pol, AKazi Kutubuddin Sayyad Liyakat, Nilima S. Warhade, Hemlata M. Jadhav, and Altaf O. Mulani (2022). Yarn Quality detection for Textile Industries using Image Processing. *Journal of Algebraic Statistics*, 11987 - 12002. ISSN:1309-3452 Vol. 13 No. 3 (2022)

[26] Patale, Jayshri Prakash, et al. "A Systematic survey on Estimation of Electrical Vehicle." Journal of Electronics, Computer Networking and Applied Mathematics (JECNAM) ISSN: 2799-1156 3.01 (2023): 1-6.

[27] Makarand M. Jadhav, et al. "Painless Machine Learning Approach to Estimate Blood Glucose Level with Non-Invasive Devices." Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications. CRC Press, 2022. 83-100.

[28] Rahul, G. Ghodake, et al. "Microcontroller Based Drip Irrigation System." (2016): 109-115.

[29] Patale, Jayshri Prakash, et al. "Python Algorithm to Estimate Range of Electrical Vehicle." Telematique (2022): 7046-7059.

[30] Takale, Swapnil, et al. "DWT-PCA based Video Watermarking." Journal of Electronics, Computer Networking and Applied Mathematics (JECNAM) ISSN: 2799-1156 2.06 (2022): 1-7.

[31] Shinde, Rahul, et al. "Analysis of Biomedical Imagell." International Journal on Recent & Innovative trend in technology (IJRITT) (2015).

[32] Mandwale, Amruta, et al. "Different Approaches

For Implementation of Viterbi decoder." IEEE International Conference on Pervasive Computing (ICPC). 2015.

[33] Takale, Swapnil, et al. "Video Watermarking System." International Journal for Research in Applied Science & Engineering Technology (IJRASET) 10.

[34] Maske, Yogita, et al. "Development of BIOBOT System to Assist COVID Patient and Caretakers." European Journal of Molecular & Clinical Medicine 10.01 (2023): 2023.

[35] Gadade, Bhanudas, et al. "Automatic System for Car Health Monitoring." International Journal of Innovations in Engineering Research and Technology (2022): 57-62.

[36] Birajadar, Ganesh, and Channappa Bhyri. "Comprehensive survey on EEG analysis for detecting brain disorders." *Mukt Shabd Journal IX (VI)* (2020): 2258-2262.

[37] Birajadar, Ganesh, and Channappa Bhyri. " cap sleep disorder identification using EEG analysis" Eur. Chem. Bull. 2023, 12 (S3), 1709 – 29.

[38] Birajadar, Ganesh. "Epilepsy Identification using EEG signal monitoring." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 12.2 (2021): 2366-2371.

[39] Yogita Maske, Mr. A. B. Jagadale et al. “Implementation of BIOBOT System for COVID Patient and Caretakers Assistant Using IOT”. International Journal of Information Technology &Amp; Computer Engineering (IJITC) ISSN : 2455-5290, vol. 2, no. 01, Jan. 2023, pp. 30-43, doi:10.55529/ijitc.21.30.43.

[40] Godse, A. P., et al. (2009)." Embedded Systems (First Edition). pp.(1-5).

[41] P. B. Mane, et al. “High speed area efficient FPGA implementation of AES algorithm”, International Journal of Reconfigurable and Embedded Systems (IJRES), Vol 7, Is. 3, 157-165

[42] A. O. Mulani, Watermarking and Cryptography Based Image Authentication on Reconfigurable Platform. Universitas Ahmad Dahlan, 2017.

[43] Akshata Kambale. et al., “HOME AUTOMATION USING GOOGLE ASSISTANT”, UGC care approved journal, Vol 32 Issue 1, 2023

[44] Dr. K. S. L. Kazi, et al. “Effect of Rotation and Projection on Real Time Hand Gesture Recognition System for Human Computer Interaction”, Journal of Gujrat Research Society, Volume 21 Issue 16, Dec 2019.

[45] R. A. Sawant, et al. “Automatic PCB Track Design Machine”, International Journal of Innovative Science and Research Technology, Vol 7, Issue 9, Sept 22.

[46] Rutuja Abhangaro, et al. “DESIGN AND IMPLEMENTATION OF 8-BIT VEDIC MULTIPLIER”, International Journal of Research Publications in Engineering and Technology (ISSN No: 2454-7875), March 2017.

[47] Mahesh Seth, et al. “Painless Machine learning approach to estimate blood glucose level of Non-Invasive device”, Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications, 2022