INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

Motivating Undergraduate Computing and Engineering Research via Educational and Scientific Drones

CH RAVI KIRAN [1], Dr. P VENKATA NAGANJANEYULU [2]

[1]Assistant professor, [2] professor & Principal
Department of Electronics and Communication Engineering

ECE Department, Sri *Mittapalli College* of *Engineering*, *Guntur*, *Andhra Pradesh*-522233

***Abstract*–** A full technical and theoretical design of a scientific and an educational hexacopter that is used as a framework to increase students' motivation in computer science and engineering and aimed at supporting interdisciplinary research in colleges is presented. The design and construction of a custom-built drone are described, with all the technical challenges and solutions. The drone is designed to carry a cluster of handheld computers (Raspberry Pis) and multiple programmable modules (e.g., GPS and weather, and pollution evaluation sensors). The drone is used as a framework that allows students to learn how to write applications in a more enjoyable way. Additionally, most of the modules are programmable with various programming languages that are typically taught in computer science introductory courses (e.g., C/C++, Python, and Java). Modules (e.g., sensors) are mounted on to the human-controlled hexacopter drone and designed to automate the collection of readings, requiring a pilot only to fly the drone. Potential results can plot graphically for analysis post-flight to support projects across multiple disciplines as needed. The presented project and the designed Multicopter drone has the potential to be adapted to offer researchers, students, scientists, and engineers a flexible and creative method to collect and analyze relevant and real data to be used for many practical research projects (e.g., atmospheric pollution data).

keywords– undergraduate research, computer science, engineering, drone, Raspberry Pi, hexacopter.

I.INTRODUCTION

As the demand on technically centered jobs has dramatically increased (e.g., companies require millions of professionals by 2020 according to IBM and other relevant studies) [6], both communities from academia and research believe that it is very important that the number of students to be proficient in STEM fields needs to be increased to meet current and future job market demands. Promoting and motivating students to excel in fields such as engineering and computer science as early as possible plays a big role in meeting our community's expectation and future job market needs. In order to increase students' motivation in science and engineering, students need to be exposed and introduced to STEM research as early as possible in enjoyable and engageable ways. Additionally, students need to learn the importance of the materials and curriculums that are taught in K12 and college levels. These goals can be met by providing and supporting instructors to prepare them to teach STEM concepts in enjoyable and effective ways. Amongst the affordable technologies and devices that have introduced to support educators to educate young students in engineering and computing, and to create easier access to STEM education is Raspberry PI. The Raspberry Pi is a small, single-board computer supported by the Raspberry Pi Foundation that was developed in 2014 for young students to engage in the study of computer science. The Raspberry Pi, or Pi, is an all-in-one computer, capable of running an operating system and offers methods to interface with the device using built-in input and output ports [1]. Programs can be written or downloaded in popular programming languages taught in schools such as C/C++, Python, and Java. Students can use this to develop an understanding of the foundation of computer science, such as logic, syntax, problem solving. Modules can be purchased by third-party manufacturers to complement and extend the capabilities of the Pi, such as sensors, microswitches, and continuous servomotors. Drones have grown in popularity and are found in educational, recreational, and commercial environments. Hobbyists can purchase prebuilt drones or custom build drones for recreation. Private industry and government regulatory bodies have used them as well, such as a contracting firm using drones to image areas of construction sites that are difficult to view. Some cities use them to image the condition

ISSN: 2057-5688

of bridges and evaluate their decay without the effort and labor of having a person safely evaluate areas that are difficult to reach. Drones in addition, can be used in educational environments as well, where concepts such as aviation, aerodynamics. can be applied and studied. In this work, the combination of a custom-built drone and a Raspberry Pi with modules is detailed, and consideration is given to the capabilities of students, reasonable budgets, and learning outcomes. With the drone and pi combination, there are limitless options in which investigators can test their product and collect real-world results. For this, this particular drone's purpose is to collect data of atmospheric pollution and emissions. The accompanying components however are modular and can be replaces with relevant modules to future studies in mind. In this work, a drone module was designed (drone, mounted sensors and Raspberry Pi's) can be used to host some servers that can be accessible by the students in real time via web interfaces. We believe that our work can motivate college and well as high school students to major STEM in general and computer science and engineering in particular. Additionally, our project can be easily delivered to the local schools in forms of educational workshops that help students appreciate the materials they study in their programs that are relevant to the computing and engineering domains. The project was designed and implemented by students and faculty members from two different disciplines (computer science and electrical engineering) which speaks volumes about the opportunities our project provides to our undergraduate students to collaborate and conduct interdisciplinary at even the freshman and sophomore levels Federal and state environmental agencies delegate industries the responsibility to maintain a permissible level of pollution in the environment [2]. Drones offer scientists and engineers a flexible and creative solution to collect and analyze atmospheric pollution data because they can ascend to areas that are difficult to see or collect data from. Utilizing such drones can offer cities, manufacturing plants, and regulatory bodies a solution to monitor environmental compliance and affordably measure the concentration of selected gases within a predefined geospatial area. The use of drones can advance our understanding of emissions and our carbon footprint by providing tangible evidence and showing where an amalgamation of pollution exists, such as at dense traffic intersections. Results can be plotted on to GIS software to visualize the data in a map. The construction of a drone and pi combination provides opportunities to study various subdisciplines of computer science and engineering in a more enjoyable way. Students have the opportunity to develop skills in programming and an understanding of computer science. Building the drone applies skills taught in mechanical engineering, electrical engineering, and teaches circuits. Students can learn about aviation,

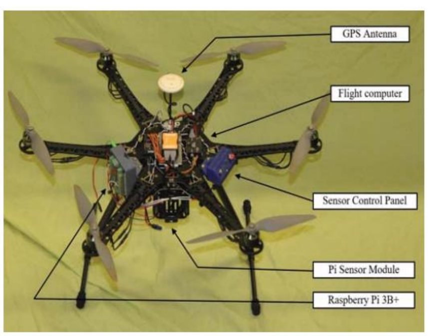

Fig. 1. The Scientific Drone Structure and Key Subsystems.

atmospheric sciences, and geographical information systems (GIS). Students can also encounter and handle general problems solving, critical thinking, and analysis. The construction of the scientific drone was split into a series of independent, sequential stages. The first stage was to design, build and test the drone and its stable flight. The second stage was the physical mount of the Raspberry Pi and accompanying sensors to the drone, accounting for the weight distribution and balance to maintain a stable flight. The final stage then the software implementation of the modules, allowing the Pi to collect relevant and purposeful data for analysis.

II.LITERATURE SURVEY

A. Initial Design, Considerations, and Component Selection

Accommodating the student's demographics, age, experience, and the nature of the project's interdisciplinary scope, designing a drone from ground zero was originally perceived as impractical. Focusing on the use of off-the-shelf components, especially with respect to the current maturity level of drones and their designs, was decided to be the most practical route. A hex rotor was chosen over a quad rotor as it provides an extra margin of safety for both the drone and any bystanders on the ground. Compromises include lower flight times and higher upfront cost, but this is believed to be a justifiable trade-off. Table 1. presents the components

INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

and shows the frame, motors and propellers along with the 537 IEEE EIT 2019

TABLE I. THE DRONE PARTS CHOSEN FOR ASSEMBLY

Qty	Item Description	Part Number	Supplier	Weight gm ea	Total Weight	Price ea	To
3	Brushless Motor CW / CCW 1each	9536000006-0	Hobbyking	116	348	$40.50	$121.
3	CCW CW 9x4.5 prop set	9329000129	Hobbyking	18	54	$3.31	$9.
6	ESC (electronic speed control)	586000005-0	Littlebee	11	66	$15.31	$91.
1	Skyline 32 w/ baseflight and cleanflight	045000041-0	Hobbyking	5	5	$25.69	$25.
1	Misc wiring and connectors		Hobbyshop	25	25	$30.00	$30.
1	Misc Hardware and fittings		Hobbyshop	40	40	$25.00	$25.
1	Main Frame	426000015-0	Hobbyking	445	445	$44.10	$44.
1	Receiver	DSMX	Spectrum	3	3	$24.99	$24.
1	Battery Charger	DYNC2015	Horizon Hobby	0	0	$69.90	$69.
1	ESC Battery 11.1v	VNR15026	Horizon Hobby	435	435	$75.99	$75.
1	PDB	090000026-0	Hobbyking	11	11	$5.90	$5.
1	Transmitter	DX6	Horizon Hobby	*	*	$199.00	$199.
6	3.5mm connectors	258000084	Hobbyking	20	120	$5.45	$32.
1	Lipo Balancing Charger		Hobbytown			$149.99	$149.
1	GPS Flight controller upgrade	DJI-Acc-Naza-M-V2	Helipal	40		$159.00	$159.
2	4S Lipo Batteries		Hobbytown	528		$129.99	$259.
				1697	1552		$1,325.

electronics chosen for the initial build.

B. Construction and Providing Disciplinary Learning Outcomes

While straightforward, the assembly of the components offer sufficient challenges to capture the attention of students. In addition, students are provided exposure to the mechanical engineering discipline due to the opportunity to design custom components. Exposure to electrical engineering is limited with respect to the motor and flight control, however there exists opportunity to work with electrical components in the design and application of the drone's sensors, modules, and its control. Control via the use of onboard computers can range anywhere from microcontrollers such as the BASIC Stamp or Arduino, to a complete Raspberry Pi single-board computer. Selecting and implementing any modules used for computation are limited by only budget and imagination. The airframe is a screw-together erector set, however careful planning of how components will mount to the frame is needed in advance to prevent, or at least reduce, disassembly to gain access to areas for modularity. The flight control board and radio receiver should be mounted in the center of the airframe followed by the electronic speed controllers (ESCs) and motors out on the arms. Lastly, wiring all these components together and establishing communication between them completes the initial build of the drone.

COMPUTATIONAL HARDWARE AND MODULAR PERIPHERALS Automating the collection and processing of atmospheric data required the installation of a small, lightweight computer on the drone itself. Many options exist that can achieve this task, notably the Raspberry Pi and the Arduino Uno. The Raspberry Pi 3B+ single-board computer was chosen over other options because of its weight, flexibility, cost, and the accessibility of components. The Raspberry Pi 3B+ weighs 42 grams, making it an ideal choice considering the restrictions of the drone's payload [3]. With an upfront cost of $35 and a plethora of accessories

ISSN: 2057-5688

available from third-party sensor kits, the Raspberry Pi, or simply Pi, offers investigators flexibility with respect to what their project goals include. In addition, the Raspberry Pi is a product of the Raspberry Pi Foundation, whose collective mission is to promote computer science education around the world, which stays consistent with mutual goals in mind [1]. Decisions were made to determine how powerful processing needed to be to collect atmospheric data, however this was found to limit the drone's payload weight and negatively impact performance. A compromise was made, which limited possible ideas such as utilizing a cluster computer or mounting a wireless receiver. Using a single Pi and the DHT11 Humidity and Temperature sensor from SunFounder Electronics [4], the Pi was fitted into a 3D-printed enclosure that was custom-designed on SolidWorks to reduce as much weight as possible. The Pi was then mounted in front TABLE I. THE DRONE PARTS CHOSEN FOR ASSEMBLY 538 IEEE EIT 2019 of the drone's body, between the intersection of the two arms. A shield was fastened above the Pi to accommodate modularity if future decisions are made to replace sensors or add more variety. A 3D-printed control panel was designed to help interface with the Pi. A smaller, NiCad battery was fastened under the chassis of the drone's body to power the Pi. Power from the drone could have accommodated the Pi, however keeping these two systems independent of each other was found to be best for public safety and maximizing the flight performance of the drone. SOFTWARE DESIGN AND IMPLEMENTATION Many operating systems have been designed to modified lightweight, ARM-architecture computers, such as Microsoft Windows IoT and modified distributions of Linux. The Raspberry Pi Foundation supports and maintains a distribution of Linux optimized for the Raspberry Pi called Raspbian, which is based on Debian Linux [5]. Raspbian was found to be the best fit because it simplified customization of the operating system such as booting with a graphical (GUI) desktop or a command-line shell. Raspbian also includes many libraries of code that can be imported for future Raspberry Pi projects, simplifying the process for students who intend to mount different sensors. In addition, Raspbian is UNIX-based and is a distribution of Linux, so many tools native to Linux were available for use, such as SSH, SCP, Git, and others. Using the DHT11 sensor, SunFounder Electronics provides sample code for use with their modules [4]. This code, written in Python 3.4, was modified and adapted to the demands of this experiment, where the logic that facilitates the Pi's communication with the module was contained into one function utilizing BCM pin 17 of the Raspberry Pi's GPIO expansion board. As the main method iterates, a function call collects the data from the module once every second. Because the module was part of an inexpensive kit, the module would often provide a corrupt reading if a checksum invalidates a reading. The code was later revised to reiterate data collections over failed checksums as fast as possible to keep a stream of data collection as consistently spaced as possible. Separate function calls were added to facilitate the storage and presentation of the data. The script would create a basic text file with a title formatted based on the system's current date/time and append the reading at every iteration. Additional function calls were made to safely power down the Pi once a predetermined number of readings were collected. The methods used to write and maintain the source code used on the Pi evolved as the project elapsed. Originally, the Python script was revised directly on to the SD card of the Pi that would be mounted on to the drone. Once the Pi had been properly fitted on to the drone, debugging code revisions became more involved and time-consuming due to the inaccessibility of the Pi's input/output ports. Solutions to work around this problem without frequent dismounts include code revisions on the same SD card applied to a separate Pi, or mounting the SD card as a physical storage volume on to a separate computer running Linux to amend files and extract data.

III.PROPOSED SYSTEM

This section talk about some of the expected challenges students and instructors could run into while building and testing the drone and the associated systems and some tips on how to solve these technical challenges.

A. Resolving Drone Instability and Substituting Components

Issues developed following the installation of the original proposed drone components. The original flight control board had proven to be problematic going through the setup

ISSN: 2057-5688

routine. These flight control boards are designed primarily for the small racing quadcopters and they often evolve quickly. The software needed to setup the boards, the firmware available for them, and the lack of reliable documentation inhibited a stable, reliable platform for use. The DJI NAZA V2 was chosen as an upgrade to a more mature and stable controller. It includes built-in GPS, return to home and scripted flight pattern capabilities. Although this controller is more expensive, it significantly improves the platform into a usable vehicle for research.

B. Initial Drone Flight Performance and Reconsiderations

drone's initial flight performance, excluding the Raspberry Pi and its accompanying modules, proved sufficient to continue with minimal adjustment. However, adding the Pi, its components, and a separate power supply negatively impacted the drone's capabilities. Performance had degraded enough to warrant looking into a more powerful motor and propeller combination. No such action was taken, however considerations for alternative equipment such as 3110-15, 780Kv motors and 10 x 3.3 Carbon fiber propellers will be addressed for future drone builds.

C. Failed Data Collection and Limited User Feedback

On November 21st, 2018, the drone and Pi combination saw its first outdoor flight in which real atmospheric data would be collected. The drone flight was safe, successful, and reached an altitude of approximately 200 feet for five minutes. The Pi's SD card was extracted for review and no measurements were taken of the flight. While difficult to assert exactly why the Pi failed to record data, the best 539 IEEE EIT 2019 prediction of what had occurred is likely a result of a permission error when the Python script is unable to create the directory in which to store the data. A directory of the same name cannot be created if one already exists, throwing an exception and halting the script. The code was later improved to elegantly handle this scenario by checking if such a directory exists before attempting to create one. Following the failed first flight data collection, the event exposed a larger problem to be handled. Because the Pi is running headless, no feedback was provided from the Pi to indicate its status and what it is doing. Investigators would have to wait until the drone lands to find out if the Pi ever booted, launched the script, and recorded and stored data. A solution to provide visual feedback led to the addition of two LEDs and a toggle switch to the Pi. The toggle switch wired to BCM pin 23 would prevent the script from collecting any data until the switch was flipped to complete the circuit. This allows investigators to exercise control over when to start recording the collection of data. A red LED wired to BCM pin 27 would illuminate only after the Pi boots, the script launches, the data file is opened to write data, and is ready to begin recording the data after the toggle switch is flipped on. An accompanying green LED wired to BCM pin 22 would slowly oscillate between on and off for every new measurement collected, spanning one full second.

D. Improving Control via Remote Shell Access

As the drone and Pi combination grew with complexity, the ability to modify the source code became more difficult and time-consuming. The I/O pins were inaccessible to connect the Pi to a monitor. The LEDs, toggle switch, shield, and interchangeable modules made utilizing a second Raspberry Pi expensive and unnecessarily redundant. Mounting the Pi's SD card as a physical storage volume on a separate computer running Linux prevents debugging as the modules were fixed to the Pi. The solution to address this inefficiency was to utilize the Secure Shell (SSH) network protocol. The use of the SSH protocol give investigators more control over the Pi without physically handling the Pi, other than the required steps of connecting the battery and flipping the toggle switch. The script on the drone could be modified through terminal-based text editors via SSH on a terminal session from another computer running Linux. Investigators can run the script from their terminal session, and the code was implemented such that while the data is collected, formatted data would print to the window as well. Investigators can run and terminate the program as much as necessary, and shutdown the Pi if desired, without physical interaction of the Pi. This improvement led to a fork in the source code, where one implementation would be used for autonomous collection, while

ISSN: 2057-5688

another version would be more interactive and allow for more control. To facilitate a connection, the host must be connected on the same local area network (LAN) as the client machine. The Pi was configured to automatically connect to a specific network at boot, and its IP address was obtained to make the connection.

E. Improving Collaboration with Git/GitHub Version Control

Maintaining the source code on one local device prohibited collaboration among multiple developers. Modifying copies of the code is an inefficient practice and introduces risk of error and loss. Limited version control and lack of physical access prohibited collective improvements on the software. This was addressed by utilizing git for version control and hosting the repository on GitHub for remote collaboration. With the repository centralized onto a remote location, the code no longer needed to be modified directly via a text editor over an SSH connection. Code could be modified on any computer regardless of its operating system. These changes would be staged, committed, and push to the remote repository. Multiple branches would be utilized to ensure that the master branch is functional and free from developmental bugs. When appropriate, the Pi would then pull those changes from GitHub via SSH. This methodology would significantly improve the collaboration and accountability of code maintenance. This allows investigators to shift their focus from mundane coding complications to the purpose of the drone's data collection.

F. Improving the Extraction of Atmospheric Data

With the Pi accessible via SSH connections and its accompanying software hosted remotely for modification and centralization, extracting atmospheric data is the only reason that would demand the dismount of the SD card and physically handling the Pi. In a follow-up test flight, this was addressed temporarily by using GitHub to store the results. A separate local branch titled "collections" was created which contained the data. This branch was then push onto the remote repository, then downloaded onto a separate computer. The "collections" local and remote branch was deleted after extraction. Creating the separate branch eventually led to chaos where the branches faced merging conflicts due to having different histories once its parent branch was modified. While this method sufficed at the time, it created unnecessary labor. Consideration was given to elegantly extract the data from the Pi, and this resulted in the use of the Secure Copy Protocol (SCP). Based on the SSH protocol, the local host can obtain the collected atmospheric data from the remote host by transferring 540 IEEE EIT 2019 the file via SCP. Once authenticated, the wildcard character (*) made the transfer of all readings done with one command, eliminating chaos, unnecessary git branches, and allowed for investigators to make progress with the evaluation of the data.

IV.RESULT

The design of the drone and Raspberry Pi combination includes the modularity of interchangeable parts. With the drone successfully built and the ability to change Pi modules when desired and using a cluster of Raspberry Pi instead of individual pieces, future work involves expanding the collection of the atmospheric data at a deeper, more investigative level. These studies can include, but not limited to, atmospheric carbon dioxide, carbon monoxide, or nitrogen oxide pollution. Measurements will be collected from areas susceptible to dense pollution, providing scientists and investigators evidence to help design solutions. The authors are grateful to the University of Wisconsin-Stout, The University of Wisconsin- Fox Valley, and the University of Wisconsin-Oshkosh for their support for this study. The authors are also grateful to the vast communities of developers who continue to develop the open-source tools that were used.

V.CONCLUSIONS

The drone and Raspberry Pi combination successfully complete stable flights, collecting and extracting data using efficient methods. The data, regardless of what that data is based on the purpose of the build, can be used for analysis for future scientific studies, and also can be graphically represented to visualize the result. By constructing a similar drone with a scientific purpose in mind, students get exposure to a large range of sub disciplines. This exposure allows them to apply these concepts in a method that can be exciting, engaging, and enjoyable, promoting their pursuit to continuing their education in STEM fields.

VI.REFERENCES

[1] The Raspberry Pi Foundation." A small and affordable computer that you can use to learn programming", 2012. https://www.raspberrypi.org/about/

[2] United States Environmental Protection Agency, Regulations.https://www.epa.gov/laws-regulations/ [3] Pololu Robotics and electronics, "Raspberry Pi 3 Model B". https://www.pololu.com/product/2759/specs

[4] SunFounder, "Company focused on STEM education",. https://www.sunfounder.com/b-sensor-kit.html

[5] Raspberry Pi Foundation, "Raspbian", 2019. https://www.raspbian.org/RaspbianAbout [6] Louis Columbus, Article, "IBM Predicts Demand For Data Scientists Will Soar 28% By 2020", forbes.com, 2019. https://www.forbes.com/sites/louiscolumbus/2017/05/13/ib m-predicts-demand-for-data-scientists-will-soar-282020/#3d064a977e3b.

[7]. G. Jagga Rao, Y. Chalapathi Rao " Robust Bit Error Rate Optimization for MASSIVE MIMOCEM System using Channel Coding Method "in Volume 8-Issue 4S2, pp. 180-184, March 2019.

[8]. M Sumalatha,Dr. P V Naganjaneyulu, and K Satya Prasad ―Low-Power and Area-Efficient FIR Filter Implementation Using CSLA with BEC‖ Journal of Microelectronics, Electromagnetics and Telecommunications,https://doi.org/10.1007/978-981-10-7329-8_14 Jan-2018,Volume -8 , Issue -3 ,ISSN: 0976-4860,pages:137-142, Springer.

[9]. A. Ravi,Dr. P. V. Naganjaneyulu ,Dr.M.N. Giriprasad ―SAR images denoising using a novel stochastic diffusion wavelet scheme‖,Springer, Cluster Computing Journal ,USA,July-2017,DOI 10.1007/s10586-017-1001-6,ISSN:1573-7543,Pages:01-09,Springer.

[10]. P SekharBabu,Dr. P V Naganjaneyulu, and K Satya Prasad ―Adaptive Beam Forming of MIMO System using Low Complex Selection of Steering Vector‖ International Journal of Advancements in Technology,Jan-2017,Volume -8 , Issue -3 ,ISSN: 0976-4860,pages:01-06, Elsevier.

[11]. D. Rajendra Prasad, Dr. P. V. Naganjaneyulu ,Dr. K. Satya Prasad ―A Hybrid Swarm Optimization for Energy Efficient Clustering in Multi-hop Wireless Sensor Network‖ Wireless PersCommun DOI 10.1007/s11277-016-3562-8 Springer

Science+Business Media New York 2016, Pages:2459-2471.

[12]. P. Ravikumar, P.V. Naganjaneyulu, K. Satya Prasad ―Peak to Average Power Ratio reduction method for Orthogonal Frequency Division Multiplexing in 4G Communication‖, I J C T A, 8(5), 2015, pp. 1703-1708m.

[13] M Sumalatha, Dr.P .V .NaganjaneyuluandDr.K .Satya Prasad ―ADVANCED FAST FOURIER TRANSFORM USING RADIX-8 BOOTH MULTIPLIER‖ ISSN 2319 - 2518 Int. J. Elec&Electr.Eng& Telecoms. 2015, Special Issue, Vol. 1, No. 3,pp (27-32) November 2015.(Impact factor – 0.454).

[14]. U.Sreenivasulu, Dr. P.V.Naganjaneyulu, ―Performance of bit-interleaved coded multiantenna OFDMA systems over space-frequency‖ National Conference on Advanced Communication Systems &Applications,held at Madanapalli 0n June 2013 , INDIA proceedings pp.161-168.

[15].T.Srinivas,Dr.P.V.Naganjaneyulu,P.Sandeep Mohan,R.Shiva Shankar ,Ch.Surender Reddy ―Face Recognition Using PCA and Bit-Plane Slicing‖ PEIE 2012, LNEE, Springer-Verlag Berlin Heidelberg 2012 , pages: 401-407, 2012.

[16]. G. Jagga Rao, Y. Chalapathi Rao, Dr. Anupama Desh Pande "Detection For 6G-NOMA Based Machine Learning Optimization for Successive Adaptive Matching Pursuit Analysis", Q3, pp. 1803-1812, Jan 2020.

[17]. P.V. Naganjaneyulu, Dr.K.Satya Prasad, An adaptive blind channel estimation for OFDM system multimedia by improved H∞ approach (for high data rate)‖, International conference on computer intelligence and multimedia applications held at Siva Kasi on Dec. 2008, vol.4, pages:252-256, Dec. 2008, Published also in IEEE computer society in the portal.acm.in.

[18]. P.V. Naganjaneyulu, Dr.K.Satya Prasad, ―An adaptive blind channel estimation for OFDM system by improved H∞ approach‖, International Conferences on advanced communication systems held at CIT Coimbatore on Oct. 2007, preceding pages:33-36.

[19]. Dr. k. Raju, A. Sampath Dakshina Murthy, Dr. B. Chinna Rao,G. Jagga Rao "A Robust and Accurate Video Watermarking System Based On SVD Hybridation For Performance Assessment" International Journal of Engineering Trends and Technology (IJETT) – Volume 68 Issue 7 - July 2020.

[20]. P.V. Naganjaneyulu, Dr.K.Satya Prasad, ―A Study of blind channel estimation in OFDM system by H∞ approach‖, National conference on Communication and signal processing held at IEEE, Mumbai on Feb 2007, NCCSP-07, pages:20-24