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"Design and Development of Aerial and Under-Water Capability Drone for Security and Surveillance"

Om Gaikwad [1]
Vastav Bharambe [2]
Gaurav Desai [3]
Shayan Ghorai [4]
Shrinjoy Ghorai [5]
Kehul Patni [6]
Mohan M. Kshirsagar [7]

Abstract: The novelty of research is that we have manifested this versatility of drones by building them aerial as well as underwater capable which make our project unique from other UAV-guided surveillance systems. This system being bi-functional can go underwater and airborne as per the requirement of the operator. The design has a quadcopter frame and 3-D printed PLA parts to mount various electronics of the drone. It also consists of two motors on each of the four arms for up thrust as well as down thrust consisting of a total of eight motors which enables it to glide in water with ease. Being equipped with a GPS makes it easy for the user to track it. The flight controller and the remote controller are calibrated using simulation software which ensure the accurate feedback to the user, Furthermore, it consists of a unique Ballast System inspired by the submarines which play a very crucial role in underwater gliding, this system uses the buoyancy principle which will help in countering the buoyant force of water by increasing the weight of the drone. The weight is increased by sucking water from the surrounding water body this process is done by actuating suction cups present on the Ballast System this will not only help to counter the buoyant force but also will ensure the stability of the drone, similarly water can be ejected out to decrease the weight of the drone. This mechanism will come into use when the user wants to achieve a certain depth in the water. The water sealing ensures no water breach in the circuit. In a report from Business, Insider drones are rapidly growing in popularity. They are still in the infancy stage in terms of mass adoption and usage, but drones have already broken through rigid traditional barriers in industries which otherwise seemed impenetrable by similar technological innovations.

Keywords: drone, flying and underwater drone, surveillance drone, security drone, 3D printed drone.

1. Introduction:

In the past decade, the world has seen unprecedented growth in technology. This has led to advancements in many areas encompassing high-end computing and electronics. Security and surveillance are imperative for many countries which have forced mankind to deploy this high-tech machinery. Drones, also known as Unmanned Vehicles (UAV) due to their tremendous capabilities and competence in the areas of aerial photography, shipping and delivery, geographic mapping, disaster management, precision agriculture, and last but not the least security and surveillance have set a respectable benchmark in the plethora of upcoming technologies. Due to these advantages and future scope, they are lucrative and show flexibility in various applications.

Drone technology is growing exponentially, from surveillance systems to photography and video shooting and now we may soon have a travelling sector undertaken by drone. Our project focuses on Underwater drone system which is a niche category of drones growing rapidly. This technology works on the flight principle of drone and underwater concept of submarine, which makes it bi-functional

capable of flying in air as well as gliding underwater. The concept of buoyancy and ballast system comes into play when moving underwater.

The novelty of this prototype is that it allows the user to fetch important underwater details which can be used in research projects, by environmentalists to compute the pollution index of the water body and discovery of underwater flora and fauna which makes it important and a step ahead of conventional drones. Since, this drone can perform both air and underwater flights it can be of greater use for a wide variety of people.

There are several advantages of this design, a single drone is capable of aerial as well as underwater flights, this being drone can be pushed to extremities whereas this feat cannot be achieved by humans in underwater conditions which will allow in collection of more important data. The ballast system can be used to decide the depth of flight for the drone, this system involves injection of water for gaining depth and releasing of water to reduce the depth. The lightweight and robust materials allow better power to weight ratio helping the drone to fly better and longer.

Researchers, environmentalists, hobbyists and students can be prospective users which get above discussed advantages as compared to a conventional drone. This will broaden the areas of research allowing better data collection from sparse areas.

Over the past few years, drones have become central to the functions of various businesses and governmental organizations and have managed to pierce through areas where certain industries were either stagnant or lagging. According to a recent report by Goldman Sachs, military spending will remain the main driver of drone spending in the coming years. Goldman estimates that global militaries will spend $70 billion on drones by 2022, and these drones will play a vital role in the resolution of future conflicts and the replacement of the human pilot. Having such alacrity by the growing world and prodigious technology, this system can have a multitude of applications, it can be used in the security of navy ships to check underwater encroachment of enemy ships or submarines this drone being small will not attract attention and can also be used for stealth operations, underwater surveillance of fish habitat which can alert various researchers if certain species are getting endangered or it can also to identify new species of certain fish or plant, underwater pollution management can also be done to keep a check on the pollutants entering the water body so that the responsible authorities can be alerted in time and can take the respective of course of action as soon as possible.

2. Literature Survey:

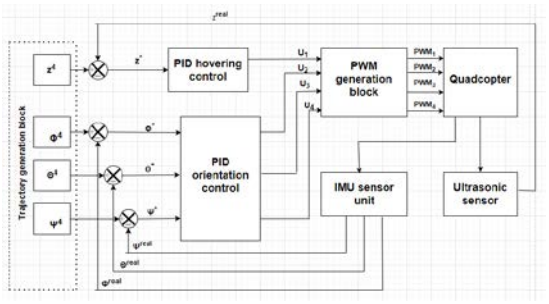
Although there has been a great amount of works presented in the domain of Surveillance and Security, majoring in Drones and UAVs, very few are concentrated on Under-Water Drone which makes it an arduous yet effective method to study upon.

We have, through this paper, implemented a State of the art research where we designed and simulated all the parts of the drone and modelled this simulation with the help of established technologies. This paper focuses on the design and the programming aspects of the drone which eventually becomes a prerequisite for the Security Applications. The width of this paper is extended from the basic components of the drone to the working principle, from Coding to Simulation, from established technologies to Future Works.

3. Working Principal:

The system work by combining the principal of aerodynamics and hydrodynamics which enables our system to work under water and in air medium. For aerial flight 4 top motors are engaged, for throttle, elevation, tilt, etc. 8 A2212 10T 13 T 1400KV brushless motors are selected which are 3-phase out-runner type BLDC motors and have an efficiency of 80%. These motors are coupled with 1045 propellers which generally draw larger currents and in result give a considerable amount of thrust, they are specially designed with an angle of 15 degrees in the end of the propeller to avoid whirlpool multi-copter flying, a single pair of motor and propeller can provide a thrust up to 1000 grams which means for the aerial flight which requires 4 motors can easily provide a thrust up to 4kg.

The motors are controlled by using a 6CH radio control transmitter. The transmitter sends the data using PWM pulse width modulated format to the receiver which is placed inside or over the quadcopter, then the receiver sends the corresponding data to the flight controller, the further process is carried out by the flight controller board which is generally a ATMEGA-128 microcontroller that transform the signals received from the receiver and directs the BLDC motors through Electronic Speed Controllers. After the command is received by the motors they act according to the signal transmitted by the transmitter.



Fig[A]: Internal Data Flow Architecture of UWD

The following functions are carried out by motors to fly:

1.The throttle is created by rotating all 4 motors at the same speed.
2.An elevation is created by rotating 2 rear motors at the speed greater than the front 2 motors.
3.The backward motion is created when the front motors have greater speed than the rear motors.
4.Aileron is created by rotating the left 2 motors at higher speed than the right motors for right turn and complete opposite for left turn.
5.Rudder action is created by rotating the diagonally situated motors moving at the same spin to rotate at a greater speed than the other two

When changing from aerial mode to underwater mode the ballast mechanism is engaged. A ballast tank is an empty compartment which can hold water inside it and it is used to stabilize the machine and to provide that stability ballast weighs the ship down and lowers its center of gravity. When seawater enters the ballast mechanism the connected pumps help to pump water in or out. At the surface of the water the ballast tanks are usually empty which provides positive buoyancy, when the water escapes from the tank the buoyancy decreases and enables it to sink.

4. Technology:

This project consists of 3 main hardware aspects which drives the entire system.

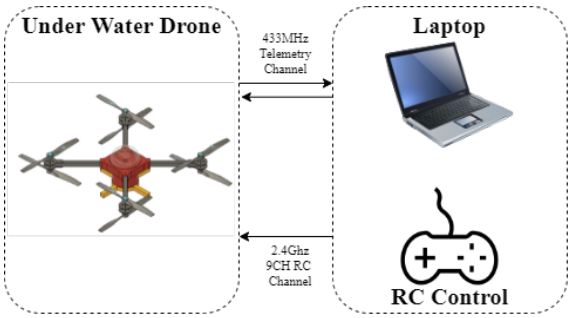


Fig: Control Flow Diagram

4.1.1 RC Remote Control.

RC i.e. Radio Control is used for controlling the system operation as per human operator's instruction which make easy to guide and navigate the system and achieve desired operation or tasks which needs to accomplish.

4.1.2 UAV / System / Drone.

This system is a general design of 4X-8 type of UAV, designed in such a way that it can carry maximum load up-to 4kg including drone weight. Also this configuration allows us to shift the pose inside water medium. Also this design can carry maximum load with less size also adds More advantages to system.

4.1.3 Portable System/ Laptop.

This is essential and crucial part of entire project as the on system microcontroller unable to handle the all processes at one time so here system comes in picture. This system is wirelessly connected with drone using a wireless module called telemetry RF 433Mhz can be used. Which controlled all the major operations of drone, and help drone to analyze the real condition with the environment and shows user live status of all processes.

4.2.1 Hardware and Design:

The entire system is designed and simulated on Autodesk Fusion360 software. Further the parts are printer on 3D printer using PLA material Poly-Lactic Acid. The parts are designed in such a way that it can be printed on any size feasibility printer. The design is inspired from 4X-8 type of quadcopter which provides high payload caring capability with the same design space. The electronics and batteries are placed maintaining center of gravity and body aspect.

The ballast system is placed bottom side of drone which sucks the water form bottom side pumps in respective load cell which enables drone to shift the CG to respective sides. This method provides automatic orientation shifting using pump ballast system.

The entire system is controlled by APM 2.6 Flight controller which can control 8 BLDC Motor and 4respective ballast system servos using Adaptive Pulse width modulation method.

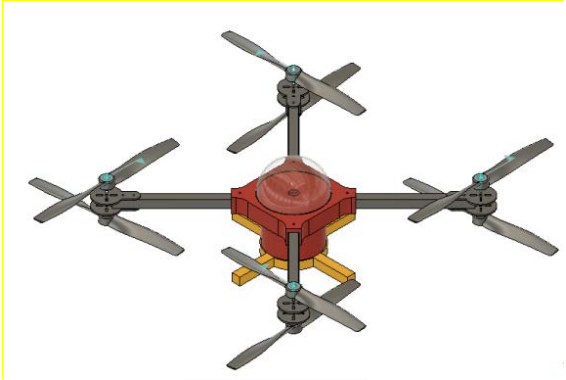


Fig: Simulated UWD

Above figure shows the simulated design of UWD which has 10x45 type of propellers.

The UWD body is completely 3D printed using PLA material with that we have used PVC pipes for 16CM arms to rest the BLDC motors. The 2 no's of BLDC motors are fixed on a BLDC plate which is specifically designed for application.

Each and every part of drone body can be removed and assembled for later use. To make it waterproof we have used silicon sealant on entire drone body which covers wires and electronics and makes it waterproof, can handle up to 3PSI pressure along with real atmosphere.

4.2.2 Software's and Programming:

The drone functionalities are programmed using Ardupilot's Mission Planner software to test the aerial flights. And programmed hydrodynamics features on separate Arduino Nano which can control all the underwater operation bypassed using a key from PWM transmitter which provides significance sing I-Bus protocall.

The functionalities of transformation from hydrodynamics to Aerodynamics we have tested using Copelia simulation tool which make easy to understand the acute and aptute parameters of system.
Such systems are very useful in virtual environment testing. We have got some significant values which we can set on real system to test it in real environment.

4.3 Components and Specifications:

A multi-medium Drone requires not only Hardware to support its structure but Electronics as well. In simple words, one can say Electronics is the Heart of an UAV, not only for Drone but for instance in any Product which has a combination of Hardware and Software. It includes Sensors, Flight controllers, GPS, ESCs (Electronic Speed Controller), Transmitters, and Telemetry Kit along with a high capacity battery is used in the UAV to provide the maximum flight time and at the same time to optimize all the other Electronics to make it work in perfect harmony.

4.3.1 APM 2.8 flight controller

Fig APM2.6 |2.8 Flight Controller

It is an upgraded version of its predecessors i.e. 2.5 and 2.6. APM 2.8 module comes with a choice of having a built-in compass which is connected using a jumper. The input voltage for this module is 12-16V, it provides various other sensors like 3-Axis Gyro-meter, Accelerometer and a high performance barometer.

APM 2.8 flight controller is the first open source autopilot system to use Intenseness' 6 DOF accelerometer/Gyro-meter MPU-6000. It has optional off-board GPS, a uBlox LEA-6H module with compass. It's barometric pressure sensor was upgraded to MS5611-01BA03 from measurement specialties, it also contains Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and USB functions respectively. It has onboard 4 Megabyte data flash chips for automatic data logging.

Power Supply	LP2985-3.3
Port	MUX(UART0,UART2,mnn12,OSD is the defaulted output)
Input Voltage (V)	12-16 VDC
Sensors	3 Axis Gyrometer Accelerometer Barometer
Processor	ATMEGA2560 and ATMEGA 32U-2

4.3.2 Radio Telemetry Kit

It is based on a 3DR telemetry kit and it is fully compatible since it runs the same firmware onboard, it is completely open source. It has a transparent serial link along with MAVLink protocol framing and status reporting. It provides support for LBT and AFA, it has Frequency hopping spread spectrum and Adaptive time division multiplexing with configurable duty cycle.

Fig: 433MHz 100mW Radio Telemetry Kit

It has Micro- USB port with 6-position DF13 connector, its maximum output is 100mW which is adjustable and it is based on HopeRF's HM-TRP module. It has 2-way full duplex communication through adaptive TDM with UART interface and the main highlight is that its error connection corrects up to 25% of bit errors. The rest of the features are that it has AT commands for radio configuration, RT commands for remote radio configuration, adaptive flow control when used with APM and it is configurable through mission planner and APM planner.

Frequency (MHz)	433
Rated Power (W)	100mW
Range (m)	1600
Receive Sensitivity (dB)	-121
Serial Interface	3.3V UART
Air Data Rates (kbps)	250
Operating Current (A)	1.1
Voltage (V)	3.6 to 7
Operating Temperature (C)	-10 to 85

4.3.3 NEO 7M GPS with Compass

Neo 7M GPS module that includes an **HMC5883L digital compass.** The **NEO 7M** is a high sensitivity low power GPS module that has 56 channels and output precise position updates at 10 Hz. Also, the **NEO 7M** delivers minimal acquisition times and high sensitivity as well. Some of the key highlights of the **NEO 7M** are:

1. It combines low power consumption and high sensitivity.
2. It is compatible with Backward **NEO-6 & NEO-5** families as well.

Fig: NEO 7M GPS with Compass for APM 2.8

Further, elaborating the above mentioned points, the **NEO 7M** provides maximum sensitivity while maintaining low system power. Also, the **NEO-7M** is optimized for cost sensitive applications as well. The updates also result in the biggest advantage so far i.e, the Sophisticated RF-architecture and interference suppression ensures maximum performance even in a GPS-hostile environment. The **NEO-7** combines a high level of **robustness** and integration capabilities with flexible connectivity options. This makes **NEO-7** perfectly suited to industrial and automotive applications. In further continuation, the **DDC** (I2C Compliant) interface provides connectivity and enables synergies with u-blox cellular modules.

Model	Ublox NEO-7M
Input Supply Voltage (VDC)	3.5 - 5.5
Position Accuracy (Meter)	2 - 2.5
Navigation Update Rate (Hz)	5
Tracking Sensitivity (dBm)	-161
Boot Time (sec)	1
Maximum Altitude (m)	18000
Maximum Speed (m/s)	515

4.3.4 RC Trans-receiver

Fig: IA6B RF 2.4 GHz 6CH PPM output with iBus port receiver

The **IA6B** is a **6-channel** 2.4 GHz Receiver that uses solid and reliable **Automatic Frequency Hopping Digital System** (AFHDS) spread spectrum technology. The **IA6B** is equipped with telemetry capabilities. In brief, **Telemetry** is the collection of measurements or other data at remote or inaccessible points and their automatic transmission to receiving equipment. **IA6B RF 2.4 GHz 6CH PPM output with iBus port receiver** has built-in connectors which allows you to use any of the optional telemetry sensors. Further on, **Telemetry** works through sensors at the remote source which measures physical (such as pressure or temperature) or electrical (such as voltage or current) data. This is converted to electrical voltages that are combined with timing data. The **IA6B** is equipped with excellent reception and interference rejection capabilities.

Model	FS-iA6B
No.of Channels	6
Encoding	GFSK
RF Range (GHz)	2.4055 - 2.475
Rx Sensitivity (dBm)	-105
Operating Voltage (VDC)	4.0 - 8.4
Data Acquisition	Yes
Antenna Length (mm)	26

5. Advantages

1. A single drone can be used for both Aerial as well as Underwater surveillance.

2. For an underwater investigation/surveillance we need around 2-3 divers and even they cannot explore properly but with this drone underwater investigation/surveillance could be done easily and with the help of this drone we can reach many places where humans cannot reach.

3. Cost Effective Design used in Aerial and Underwater Survey

4. Immediate switching between air and water is as easy as switching a fan ON and OFF.

5. Material used in the drone is lightweight and robust. (MATERIAL USED)

6. The Ballast Mechanism used in the drone helps to control the body of the drone underwater which helps the drone to float on the water as well as maneuver underwater. (BALLAST MECHANISM)

7. The external payload of the drone in air is 1 kg which is more than enough to carry most of the materials needed for emergency services.

6. Applications

6.1. Military

a. Border security surveillance, tracking of illegal activities without risking lives.
b. Launching missiles and torpedoes.

6.2. Safety

a. For search and rescue operations.
b. Drone equipped with air quality sensors monitors and provides real time analysis at various elevations.
c. Disaster relief by providing intelligence across an affected area.
d. Presence of thermal sensors gives drones night vision and makes them a powerful tool for surveillance. Drones are able to discover the location of lost persons and unfortunate victims, especially in harsh conditions or challenging terrains. Besides locating victims, a drone can drop supplies to unreachable locations in war torn or disaster stricken countries. For example, a drone can be utilized to lower a walkie-

talkie, GPS locator, medicines, food supplies, clothes, and water to stranded victims before rescue crews can move them to someplace else.

6.3. Cargo Transport

a. Major companies like Amazon, UPS, and DHL are in favor of drone delivery. Drones could save a lot of manpower and shift unnecessary road traffic to the sky. Besides, they can be used over smaller distances to deliver small packages, food, letters, medicines, beverages and emergency medical specimens to any area or terrain in a short span of time.

6.4. Marine and Land Surveys.

a. Inspection of bridges both above and below the water.
b. Evaluation of seaborne environmental incidents, like oil spills and algae blooms.
c. Crowd monitoring, counting wildlife, fire and large accident investigation.
d. Exploration of marine life.

6.5. Leisure

a. For aerial and underwater photography, this drone can be used to capture footage that would otherwise require expensive helicopters, cranes or submarines. Fast paced action and sci-fi scenes could be filmed by this drone thus making cinematography easier.
b. Hobby and recreational purposes.

6.6. Journalism

a. Journalists can use the drone for collecting footage and information in live broadcasts.
b. Live broadcasting of sports (any kind of sport, water or land) will be much easier with the use of this drone.

6.7. Geographic Mapping

a. Available to amateurs and professionals, the drone can acquire very high-resolution data and download imagery in difficult to reach locations like coastlines, mountaintops, and islands.
b. These are also used to create 3D maps and contribute to crowd sourced mapping applications.

6.8. Weather Forecast

a. The drone can also be developed to monitor dangerous and unpredictable weather.
b. Since they are cheap and unmanned, this drone can be sent into hurricanes and tornadoes, so that scientists and weather forecasters acquire new insights into their behavior and trajectory.

6.9. Precision Agriculture

a. Farmers and agriculturalists are always looking for cheap and effective methods to regularly monitor their crops. The infrared sensors in the drone can be tuned to detect

crop health, enabling farmers to react and improve crop conditions locally, with inputs of fertilizer or insecticides.

b. It also improves management and effectuates better yield of the crops.

7. Future Scope

The current scenario of UAVs stands way ahead of technological evolution in the automation sector. Current methods describe drones to be very useful in human interaction with nature. These mini flying robots have immense capabilities despite being small in size. Presently, they are not as autonomous, a continuous eye at sight is required to monitor each moment and to control every movement.

Addressing the trends in UAVs, it protrudes in the main front of complicated applications like Artificial Intelligence, Unmanned Traffic Management, Internet of Things, Smart Cities Initiatives, Robotics, etc.

Due to their capabilities, they are widely used in every aspect of domains from mini to major areas, some of the common capabilities of these UAVs are their Range, Payload capacity, Endurance, and Data linkage or Communication protocols.

However, considering design loopholes in the current technological approach, the main issue with designing these robots is security management, the insecure protocols lead to the installation of malware. Moreover, the wireless communication between the drone and the controller disturbs environmental sustainability.

Despite all the loopholes, future robotics might be able to help us to overcome all the inadequacy engaged with the current technological aperture.

Underwater drones are also made for the futuristic purpose of serving in areas where humans cannot reach with current technology. This multi-purpose drone with Underwater & Aerial capability can be used in oceanic current and temperature measurement, species identification, ocean bed mapping, etc. These mini-sized drones can also be used in military inspection and research. The novel feature of our prototype is the immediate switching between air and water state helps the user to perform multifaceted tasks without any delay.

Further, considering more advancements in the coming future of drones, using Artificial Intelligence and Machine Learning, they can be made self-intelligent and autonomous. Adding more compact and multi-functional sensors will make the drone more efficient and user-oriented.

8. Results and Conclusion

As per our research and findings this drone has range of 2KM line of sight in aerial medium, along with that drone can achieve 10 Feet depth underwater with prototype system. The system work with LI-ION battery 11.1V 4800mAh rechargeable battery. As per our load test results this system is capable of handling 1.4Kg Payload. This drone can work up to 30+Min underwater and in Air 18+Min.

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10. References

a. https://app.diagrams.net/
b. https://doi.org/10.1016/j.promfg.2015.07.290/
c. https://reviewkadukan.com/best-fishing-drones/
d. https://www.pobonline.com/articles/100510-airwater-drone-could-simplify-surveying
e. http://iosrjen.org/Papers/Conf.19018-2019/EXTC/Volume-10/4.%2013-16.pdf
f. https://www.hindawi.com/journals/jat/2019/9063232/

11. Authors Information

1. ***Om Vinayak Gaikwad***
Pursuing B Tech in Mechatronics Engineering from Symbiosis Skills and Professional University, Pune, Email ID - omvgaikwad@gmail.com

2. ***Vastav Bharambe***
Pursuing B Tech in Mechatronics Engineering from
Symbiosis Skills and Professional University, Pune.
His research interests include Deep learning, Natural Language Processing and image processing. He is currently a Research Assistant in NLP focusing on Speech synthesis.
Email ID – vastavbharambe@gmail.com

3. ***Gaurav Desai***
Pursuing B Tech in Mechatronics Engineering from
Symbiosis Skills and Professional University, Pune
Email ID - gauravdesai756@gmail.com

4. ***Shayan Ghorai***
Pursuing B Tech in Mechatronics Engineering from
Symbiosis Skills and Professional University, Pune
Email ID - shnghorai@gmail.com

5. ***Shrinjoy Ghorai***
Pursuing B Tech in Mechatronics Engineering from
Symbiosis Skills and Professional University, Pune
Email ID - shrinjoyghorai@gmail.com

6. ***Kehul Patni***
Pursuing B Tech in Mechatronics Engineering from
Symbiosis Skills and Professional University, Pune
Email ID - kehulpatni@gmail.com

7. ***Mohan M. Kshirsagar***
Founder and Director at MAK TECHNOLOGY LLP Pune.
Email ID -maktechnologyllp@gmail.com