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Underwater Object Detection using Drone

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Abstract: Micron SONARs are some of the most widely used imaging system for obtaining large scale images of the seafloor. We propose in this paper an aerial drone to effectively detect underwater mines using the sonar attached to a drone, thereby enhancing the safety of maritime navigation and protecting valuable maritime assets. We also proposed in this paper the simulation of drone on Gazebo where this simulator can show the flight of the drone in air. The simulation of drone in Gazebo allows for comprehensive testing and visualization of these flight capabilities, ensuring its effectiveness in real-world scenarios. The integration of advanced and innovative development in technology not only addresses the challenge of mine detection but also demonstrates innovation in maritime security solutions.

Keywords: Micron SONAR, ROS, Gazebo.

I. INTRODUCTION

1.1 Background

In pursuit of enhancing maritime security and safeguarding underwater environments, this project introduces an innovative solution: an underwater drone equipped with advanced mine detection capabilities. By seamlessly combining technology and environmental stewardship, our mission is to mitigate risks posed by submerged mines, ensuring safer navigation and preserving the careful harmony of ocean life method.

1.2 Motivation

The motivation behind the endeavor stems from the understanding that sonar-based drone detection offers a versatile and precise solution. By leveraging acoustic signals and cutting-edge sonar systems, we aim to enhance the accuracy of mine detection, providing a proactive approach to identify and neutralize potential threats in aquatic environments.

Our commitment to this project is fueled by the desire to mitigate risks associated with conventional mine detection methods, fostering safer navigation and securing vital maritime assets. Detecting various underwater objects using the TRITECH MICRON SONAR, which will be suspended from the Drone. The drone will be positively Buoyant, and will float on the surface of the water, as the Sonar collects data and sends it to the onboard computer. The main objective of this drone is to detect underwater floating mines.

1.3 Objective

The objective of this project is to effectively detect underwater mines using a sonar attached to a drone, thereby enhancing the safety of maritime navigation and protecting valuable maritime assets.

II. DETECTION OF UNDERWATER OBJECTS

1.4 Operating Principle

The operating principle for scanning SONAR works by sending out sound pulses into the water to see what's there. Sonar figures out how far sound traveled in water by using its speed and the time it takes for echoes to come back.

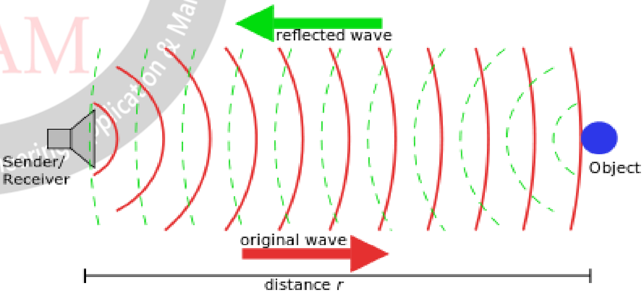

Figure II.1:Operating principle of scanning SONAR

2.2 .1 Target Reflectivity

If an object in the water is made of something that's a lot denser or lighter than water, like gas, rock, concrete, or metal, it will bounce back a lot of sound and create clear echoes on the SONAR.

When SONARs detect echoes from mud, silt, sand or plants, the echoes are faint because these materials either match the density of water or soak up sound. On the screen light colors show strong echoes, while dark colors show weak echoes. It's like using colors to show how loud or quiet things are underwater.

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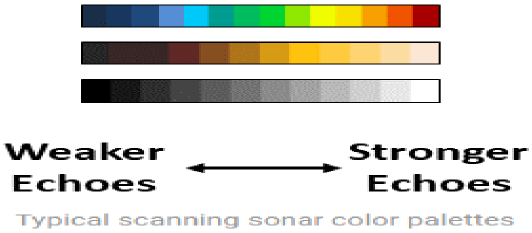


Figure II.2:Scanning sonar color palettes

1.5 Acoustic Beam Patterns:

Think of scanning SONARs like shining a flashlight in the dark. You can only see the area illuminated by the flashlight, while the rest stays dark. Similarly, SONARs only "light up" a specific area with sound waves, revealing what's there while the rest remains hidden.

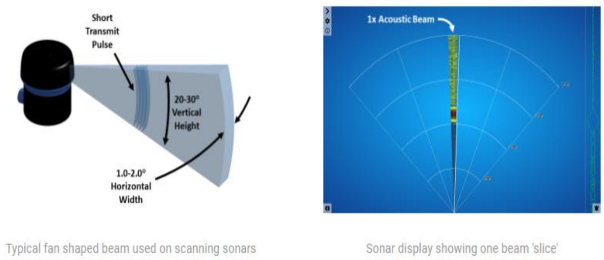
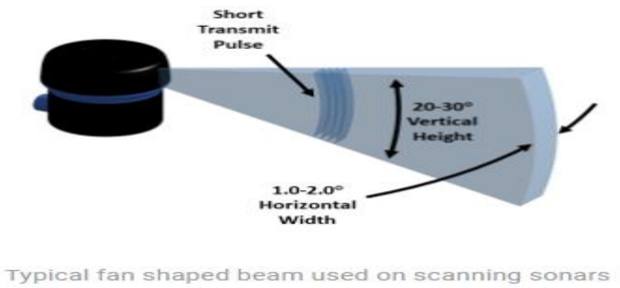
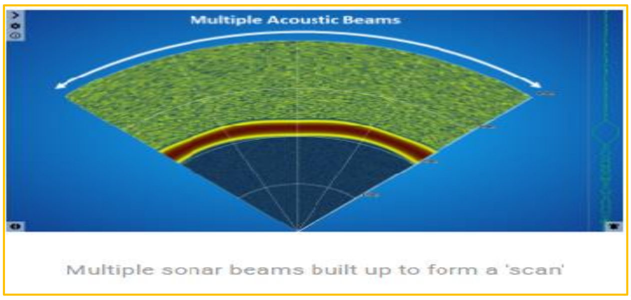


Figure II.3:Single slice of scanning sonar emerging from transducer head and single slice acoustic beam displaying in the SEANET PRO software.

To create an image or find targets, the scanning sonar's transducer head moves around using a stepper motor. It swings in an arc to gather slices of data, which are then pieced together into an image on the display screen. It's like the sonar is taking snapshots from different angles and putting them together to show what's there.



(a)



(b)

Figure II.4:(a) Typical fan shaped used on scanning sonars and (b)Multiple acoustic beam built up to form a scan displayed in SEANET PRO software.

1.6 Target Visibility

When objects are within the sonar's horizontal and vertical beam range, they get "lit up" by sound waves. These waves bounce off the objects and return to the sonar, where they're picked up and turned into an image. It's like the sonar is shining a sound spotlight on things to see them better.

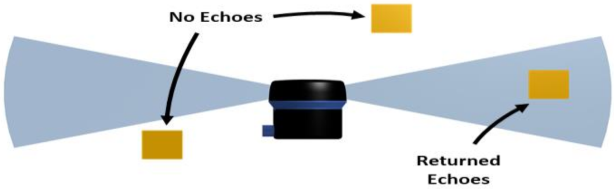


Figure II.5:Figure showing target visibility.

1.7 Vertical Arrival Angle and Slant Range

Scanning SONARs can't tell the difference between objects that are at the same vertical level. So, if two targets are directly in front of the sonar, one above the other, the sonar will show them as one combined result because it can't distinguish between their echoes. It's like seeing two things stacked on top of each other and only being able to see them as one.

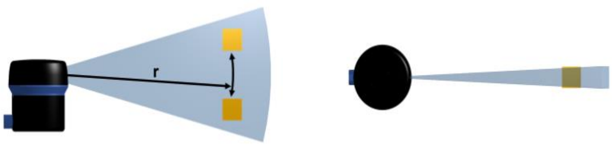
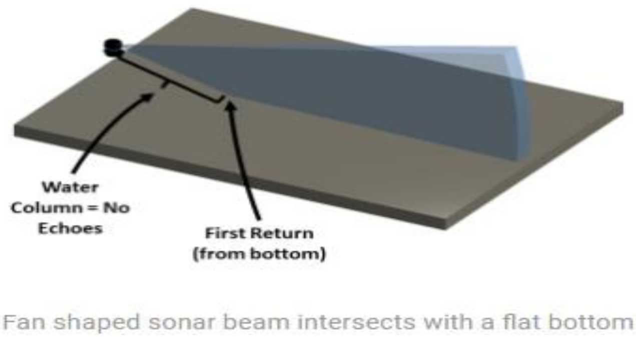


Figure II.6:Vertical arrival angle and slant range

1.8 Viewing the Seabed

Think of scanning SONARs like shining a flashlight in the dark. Just as the flashlight's beam can't distinguish between objects at different heights, SONARs can't tell targets apart vertically. So, the images they display are like looking down from above, giving a "top-down" view of what's there. It's like seeing everything flattened out as if you were looking at a map from above.



(a)

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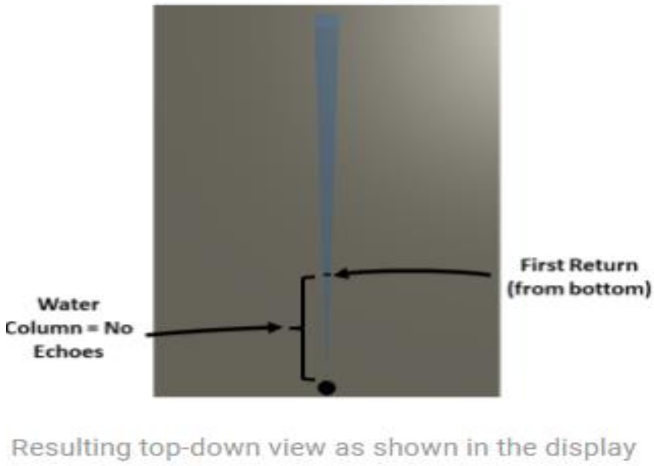

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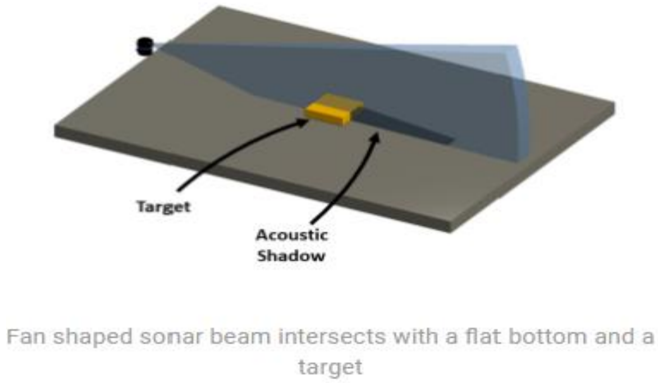
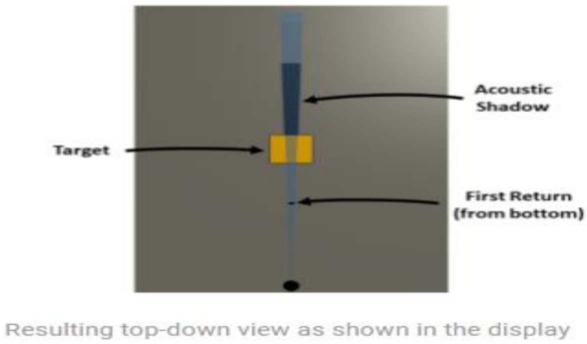


(c)



(d)

Figure II.7:Figure (a) and (b) fan shaped sonar beam intersects with a flat bottom and a target, figure (c) and (d) the shows resulting top-down view.

1.9 Bottom Visibility

When the sonar is low and angled steeply downward, it can only see a small part of the area below. But if it goes higher up, it can shine its sound waves over a broader section of the ocean floor. It's like moving a spotlight higher to light up more of the stage.

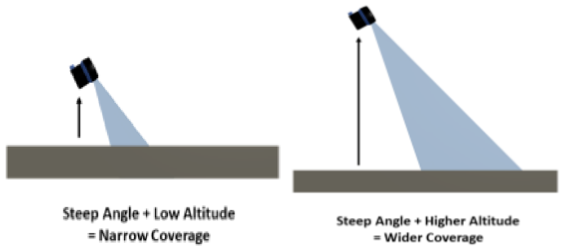


Figure II.8:Bottom visibility of narrow and wider coverage.

When operators are looking for targets underwater, they get the best results from the sonar by finding the right balance. They should keep the sonar at a certain height above the sea bottom and angle it slightly downward. This way, they can see the furthest distance on the sea bottom while still getting strong signals from the sonar. It's like finding the sweet spot to get the clearest picture without sacrificing range.

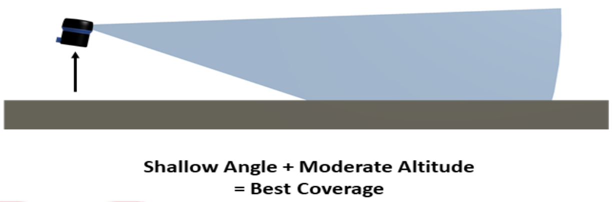


Figure II.9:Bottom visibility of best coverage.

1.9.1 10% Rule

As a rule of thumb, scanning sonars, whether sidescan or mechanically scanning, can cover about 70% of the seabed in a given area. To achieve this, they should be angled downward by 10-15 degrees and placed at an altitude equal to 10% of the operating range. For instance, if the range is 10 meters, the sonar should be 1 meter above the sea bottom. If the range is 20 meters, it should be 2 meters above. This setup helps to get good coverage while maintaining signal strength.

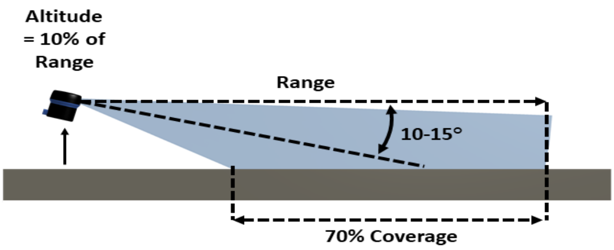


Figure II.10: 10% Rule

1.10 Acoustic Shadows

The flashlight analogy can continue to be used when the sonar locates a target on the sea bottom in order to help determine the height, shape and orientation. An “acoustic shadow” will be shown behind an illuminated target in the same way that a “visible light shadow” will be visible behind an object illuminated with a flashlight.

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1.10.1 Altitude

When the sonar is up high and angled steeply downward, the acoustic shadows behind targets will be shorter. These short shadows can be tricky to spot and might make it harder to figure out what the target is like. It's like trying to see a small shadow when the light is shining from above at a sharp angle.

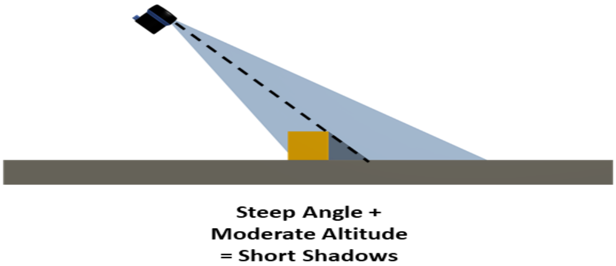

Figure II.11:High altitude results in short shadows.

When the sonar is closer to the bottom and angled less steeply downward, the acoustic shadows behind targets will be longer. This makes it easier to understand what the targets are like. It's like seeing a bigger shadow when the light is shining from closer to the ground and at a gentler angle.

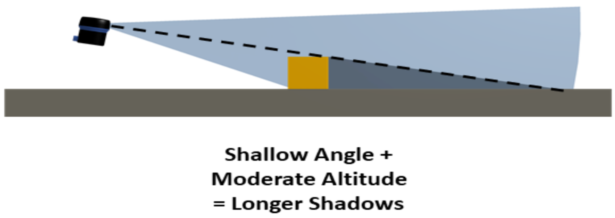

Figure II.12:Low altitude results in short shadows.

1.11 Understanding Echoes

Surfaces of targets that are perpendicular to the sonar will yield the strongest returned echoes, while surfaces at other angles will cause the acoustic waves to reflect away from the sonar, yielding weaker returns. Surfaces of targets that are perpendicular to the sonar will yield the strongest returned echoes, while surfaces at other angles will cause the acoustic waves to reflect away from the sonar, yielding weaker returns.

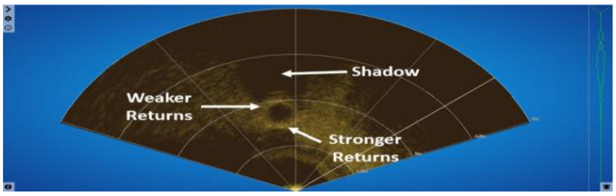

Figure II.13:Understanding echoes of different colors in SEANET PRO software.

1.12 Step Speed

This contains 3 speed options (controlled through software)

1. “Normal” ill produce the best resolution at slower speed.
2. “Fast and Very Fast” are useful for searching objects.

Sonar reflections of isolated small objects give no indication of shape or attitude. Man-made structures such as platforms or rock walls tend to have regular patterns that are easier to identify. When close to large objects, or in a depression in the seabed, that the viewing range may be severely limited. When searching for objects, we have to hold the sonar heading as steady as possible to stop the image blurring. Depending on the water depth and vehicle depth, there may be ring like echoes. These can be caused by surface or seabed reflection and may be difficult to avoid. There are 4 range resolutions available, selected from the Main Menu. As the resolution is increased from Low to Medium to High to Ultimate, the sonar display will show better resolution, but at a lower scan speed. Use of a lower resolution will give faster scan speed, but with coarser detail. When searching for smaller targets close by, select a higher resolution mode and when searching for large targets at long range use lower resolution.

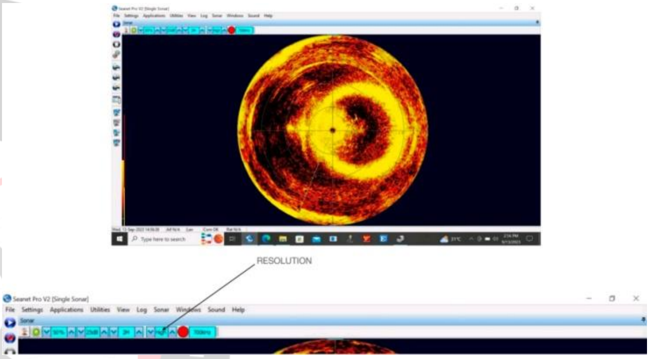

Figure II.14:Three step speed options in SEANET PRO.

1.13 Operation with SEANET PRO

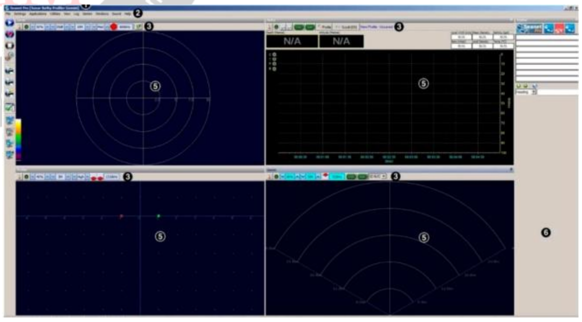

Figure II.15:Operation with SEANET PRO.

The main areas of the display are:

- Display Header: This part of the screen is used for system/software identification.
- Menu Bar: This is where system setup files can be accessed. Printing, application selection, color scheme setup and logging are some of the features that can be accessed in this screen area.
- Status Bar: This part of screen is used to display system status information, logging status/ progress and job specific information.

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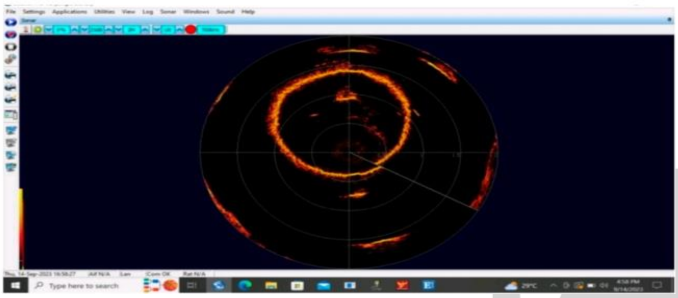
- Settings bar: This is where the sensor can be controlled and configured. The settings bar is at the top of every display window for each device that is connected to the system. It includes tools setup button, Led indicator, and RAT dials and buttons.
- Sensor display area: This part of the screen is where the main sensor data is displayed.
- Sidebar: This is where serial input data and user text can be displayed.

1.14 Testing of Micron Sonar

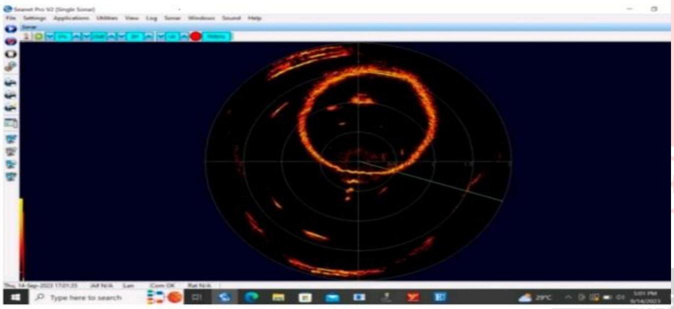
Experiment 1

Metal Cylinder (18*20cm)



Experiment 2

Plastic Sphere



Experiment 3

Hollow Plastic Box

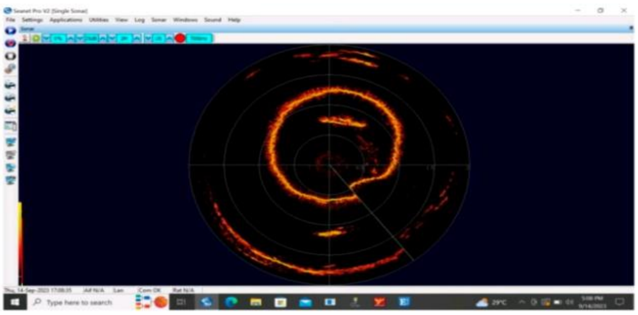


Figure II.16:Testing of Micron Sonar using SEANET PRO application was conducted with different objects.

Quadcopter Parts:

Parts Name:

1) *Tarot Iron Man 650:* It is a quadcopter frame. It has frame size of 690mm and weight of 526g.
2) *T-motor Propeller 17*5.8inch:* It has weight of 26.5g of single blade.
3) *T-motor MN4014 KV330:* It is a BLDC Motor. It has 1050g thrust at 50% throttle and 2600g thrust at 100% throttle. It has 171g weight.
4) *T-motor Alpha 60A 6S:* It is a waterproof ESC for BLDC motor. It has weight of 62.8g.
5) *Tattu 1600mah-15C 22.2V:* It is a 6S 22.2V 16000mAh 15C Lipo Battery with XT90-S connector. It has 1915g weight.
6) *Holybro Pixhawk 6C PM02 M89 Combo ki:* It is a flight controller and has 20g weight.
7) *3DR Single TTL MINI Radio Telemetry 433MHz 500mW for PIXHAWK and APM FC:* It is a telemetry module and has weight of 37g.
8) *Radiomaster TX16s:* It is a radio controller radiomaster TX16s MKII HALL V4.0 ELRS Radio with RP1 Express LRS 2.4ghz Nano Receiver.
9) *Tritech Micron SONAR:* It is the sonar for detecting underwater objects. It has weight of 324g in air and 180g in water.
10) *NEO-M8N GPS module with compass for APM:* It is a GPS module with weight of 26g.
11) *GPS module stand:* It has 20g weight.
12) *Walksnail Avatar VRX + Walksnail Avatar HD Kit V2-32GB w/Gyro COMBO:* It has 7.2g Camera, 17g VTX and 2g Antenna.

Calculations:

(1) *Total Weight without Payload = 3644gm=3.644kg*

*at 17*5.8inch Props = 1050gm force*

*so hovering thrust (at 50%) is 1050*4 = 4200gm*

*current drawn is 4.7amps * 4 = 18.8amps*

Thrust to weight ratio = 2.54

So, flight time(t)

t = Battery capacity x Battery discharge x 60 / Average Amp. Draw

t=(16000/1000)(80/100)*(1/18.8A)*60 =40.85mins (at 50% throttle)*

(2) *Total Weight without Payload (lifting from water) = 5000gm(approx.)*

*so hovering thrust (at 65%) is 1580*4 = 6320gm*

*current drawn is 8amps * 4 = 32amps*

So, flight time(t)

t = Battery capacity x Battery discharge x 60 / Average Amp. Draw

t=(16000/1000)(80/100)*(1/32A)*60 =24mins (at 65% throttle)*

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Figure 0.1:Calibrated Quadcopter

Simulation

Simulation of the Drone is done on Gazebo. Gazebo is an open-source 2D/3D robotics simulator that began development in 2002. Gazebo is opened on the Robotic Operating System(ROS). ROS is an open-source framework that provides libraries and tools to help software developers create robotic applications. The basic requirement for running ROS is Ubuntu or Linux Operating System. For opening Gazebo on ROS, the ROS should run on Ubuntu.

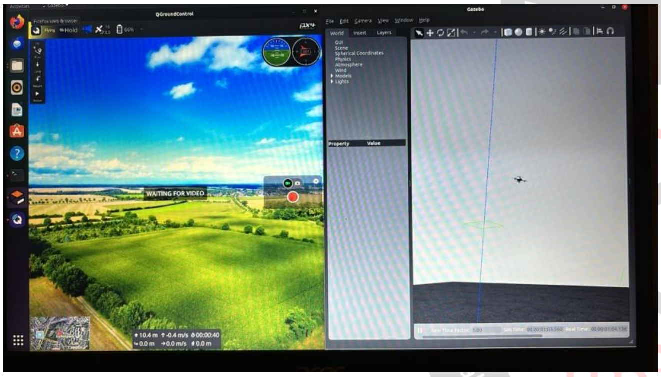
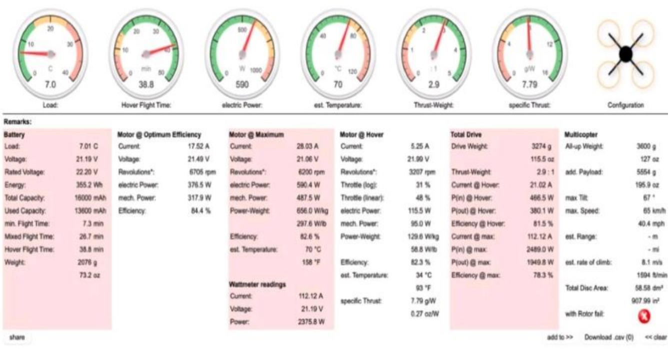


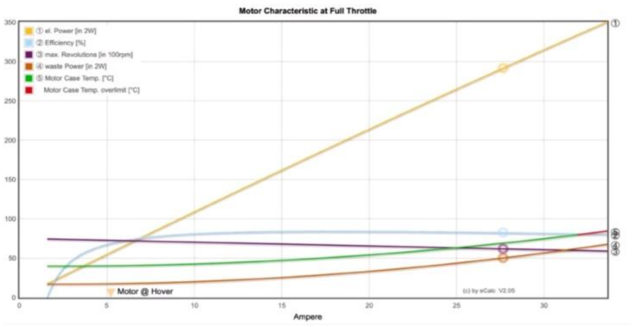
Figure 0.1:Gazebo opened on ROS showing simulation of drone.

III. RESULTS AND DISCUSSIONS

1.15 Results



(a)



(b)

Figure III.1: Results showing the (a)motor thrust estimation, flight time, thrust-weight ratio and electric power in eCalc simulator and (b)its characteristic graph of motor at full percent throttle.

1.16 Discussions

By inputting the values of model weight, frame size, cell capacity, max. discharge, esc maximum current, motor KV and propeller size in the eCalc simulator. We set the model weight to be 3600g so that additional payload becomes 5554g which is 5.6kg and propeller size to be 17*5.8 inch. We get the following main output shown in the figure 5.1(a) as Load of 7.0C, 38.8mins hover flight time, 590W electric power, est. temperature of 70 degree Celsius, 2.9 thrust-weight ratio and specific thrust of 7.79g/W. Figure 5.1(b) shows the graph of motor characteristics at full throttle. The yellow line shows the efficient power(in 2W), the blue line shows the efficiency(%), the purple line shows the max. revolutions(in 100rpm), the orange line shows the waste power(in 2W), the green line shows the motor case temperature (deg. Celsius) and the red line shows the motor case temperature overlimit (deg. Celsius).

Social Applications

Our drone can be implemented with a camera attached for object detection and also capturing the image in place of Micron Sonar. This drone was calibrated and has the calculated hover flight time of 40.85mins. This drone can help us in underwater fish surveillance which can be used by fishermen to track movements of fishes. This drone is also used in defences for underwater detecting mines to monitor and track the exact location of mines under the seabed.

IV. CONCLUSION

In this paper we proposed a method of detecting underwater seabed objects using MICRON SONAR attached to Quadcopter. The transducer head inside the scanning sonar finally analyzes the sonar images and shows the image on the SEANET PRO software. And reported this experimental results to show the proposed method efficiency. The calculated hovering flight time value shows nearly equal flight time value in the

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simulator. Finally desired output of drone flight and object is shown successfully in simulator using Gazebo.

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