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SUBMERSIBLE DRONE: LOCALIZATION OF MISSING PEOPLE'S VICTIMS OF DROWNING

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Abstract. This innovation has its main focus in the location of missing drowning victims using a more efficient and fast way, which benefits the professionals that work in such operations. These professionals require a safer environment for work, which can benefit also the families of the victims, who will have a faster response about the victim's whereabouts. During a rescue operation, diving is the most difficult task, exposing the diver to constant risk, such as being washed away by strong currents or being stuck at previously unknown obstacle. The task requires that the professional stays long times underwater and, even the smallest mistake can turn the rescue diver into the victim. A significant improvement in the professionals safety can be acquired in a very efficient way by the utilization of a submersible drone, since it require less human effort in the location of the victim and, thus allowing a more precise location and ensuring the safety of the professionals involved. Therefore, the device is a unmanned vehicle, comprised by an Remotely Operated Underwater Vehicle (ROV) attached to a drone. The main objective of the device is the location of drowning victims using real time first person images of the underwater environment.

Keywords: submersible drone, drowning victims, firefighters.

1. INTRODUCTION

Presently we live in a risky society, in which some professions, firefighters for example, work effectively in the management of these risks and in the control of adverse situations when the situation is, inherently, dangerous. Drowning is considered the fourth cause of accidental deaths in adults and the third cause among children and teenagers around the world. According to the Civil Defense Ministry (Brazil, 2015), 500,000 people drown every year worldwide. In Brazil, drowning appears as the second biggest cause of accidental death, annually killing 7,500 Brazilians. However, the exact number is unknown due to the reason that a significant number of missing people cases are not reported.

Scuba diving, is considered the second most dangerous activity in the world, being surpassed only by space exploration. Professional rescue divers are trained to search and rescue drowning people and underwater objects, using autonomous breathing equipment. The divers experience on a daily basis, low visibility of blurred water, predominant in lakes and rivers. Working underwater give rise to the water pressure, which affect the bodies of the divers, requiring them to adapt themselves every time they need to go underwater.

Underwater search is a difficult task and requires long periods of continuous work and, thus, increasing the risks involved, since any error can expose the whole search team to dangerous situations.

The safety of the rescue team is the initial priority and thus, the knowledge from different fields should be used in the development of a system that could benefit from the advantages of robotics. The benefits include the reduction in the number of professionals involved in the operations and an increase on the general safety of the divers. The benefits result in the optimization of the maneuvers, adding the flexibility of the robotic systems with the intelligence, creativity and versatility of the human operator. In order to have the idea working properly, it was needed to ensure that the professionals had the sensation of being underwater despite being controlling the device remotely. The development of a submersible drone, intuitively controlled by the operator, was chosen in order to achieve this objective. The other goals were the acquisition and maintenance cost reduction via an exclusive design.

The drone is equipped with a geoprocessing system, a sonar and other tools, for example, adequate propellers, in order to have the best maneuverability. A camera with first person view, along with underwater light, is used so the operator can perform the required movements.

A waterproof, robust, flexible, with low cost and good precision drone was required in so the project become minimally feasible for multiple purposes.

2. DESCRIPTION OF THE ROBOTIC MANIPULATOR

The employment of a submersible drone becomes a efficient, effortless and riskless alternative to be used in underwater search and rescue operations. The professionals would only start the operations after the precise location of the victim and the proper mapping of the surroundings thus, ensuring the safety of the divers involved on the operation.

The objective of the submersible drone is to guarantee a safe operation for the rescue team professionals and to ensure that the search be maintained regardless of weather and/or luminosity conditions. Another advantage of this technique is a reduced rescue time, which can benefit the family members of the victims.

After researching robotic techniques and aircraft dynamics, the knowledge of different areas were used, for example, the manipulation of drones, also known as UAV's (Unmanned Aerial Vehicles), aircrafts which are capable of flying long distances. Also the usage of Remotely Operated Underwater Vehicles (ROV's), which cameras and sensors can be used in order to inspect the surroundings, making it possible to the rescue team to be virtually present in unreachable or dangerous places.

3. MATERIALS AND METHODS

This section present all information about the technologies and materials used in the development and tests of the prototype.

3.1 Computer Aided Design (CAD)

The initial step of the project was the 3D modeling, as shown in Fig.1, of the prototype using a CAD tool. The structure, which was later used in the fabrication process is shown in details in Fig.2. The fabrication made possible improvements towards the cost/benefit analysis and also to facilitate the construction in order to present the prototype operation.
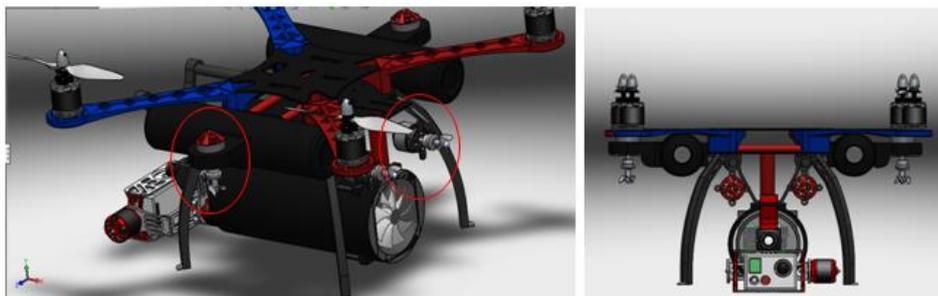

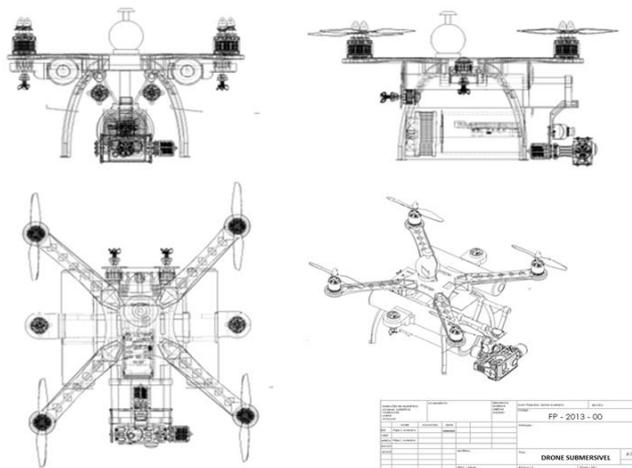Figure 1. Prototype 3D model

Figure 2. Technical Drawing used in the fabrication

For better a comprehension about the constitution of the "submersible drone disposition", in Fig. 3, the exploded-view drawing of the prototype is shown:
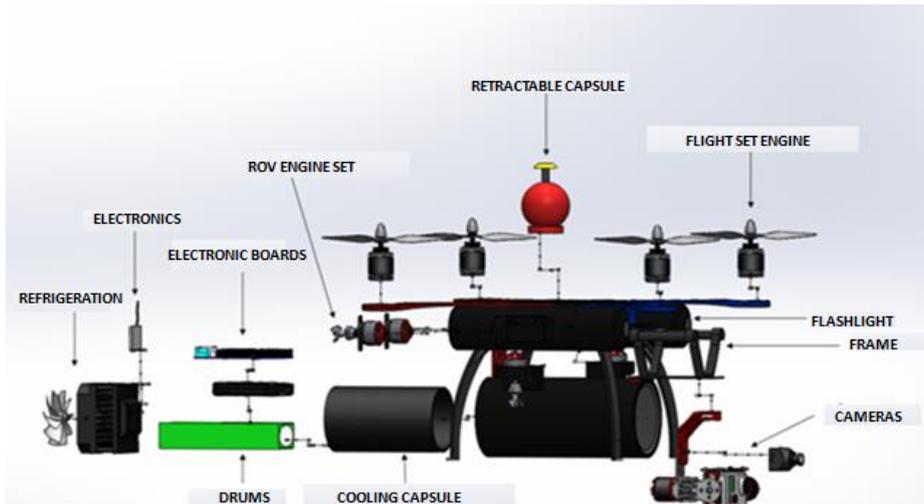
Figure 3. Prototype's exploded-view drawing

3.2 Hardware

According to Magni (1997), a Flight Control System (FCS) main function is to contribute to a safe and economic aircraft operation.

A UAV autopilot is responsible for all aircraft's dynamic calculations and to keep a stable flight during take-off, the flight itself and landing (Artale *et al*., 2012). This drone's situation perception system (based on sensors) and the conception o proper responses (through pre-programmed calculations) is named as "law" of control (Pratt, 2000). However, in some situations, the pilot may change the flight mode and, thus, changing the "law" of control.

Most of modern flight controllers, Pixhawk and Ardupilot, for example, already have Inertial Mesurement Units (IMU's) in its architectures. The IMU is an electronic circuit equipped with accelerometers, gyroscopes and, sometimes a compass, which provide the flight controller with information about UAV's position (Pixhawk, 2015).

The flight controller board diagram used in the prototype PIXHAWK 4, which is claimed to be the best FCS currently being sold, is shown on Fig.4. Also in the diagram, the component connections used in the development of the prototype are shown.
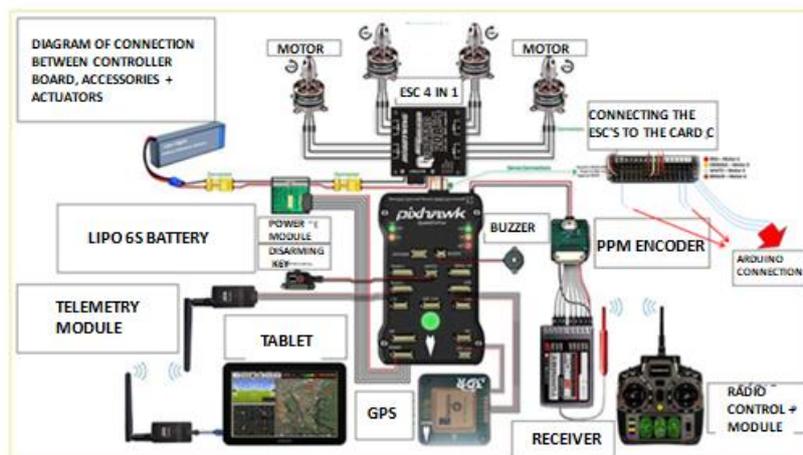

Figure 4. Controlling board connection schematics

On the following step, the flight controlling board was connected with the Arduino board (ARDUINO CONEXÃO, Fig.4). The Arduino board has the objective to control the actuators in order to reconfigure and to ensure the correct aquatic route, shifting from aerial coordinates into aquatic coordinates while the device is submerse. Also, the board seeks to keep the behavior of the drone the uniform, even when underwater. The luminosity of the surroundings and the calculations for a possible route towards de victim's location are also in the scope of the Arduino board.

On Fig.5 are demonstrated the connection scheme of the aquatic propellers, sonar, Arduino board, and the connection between them and the controller board.
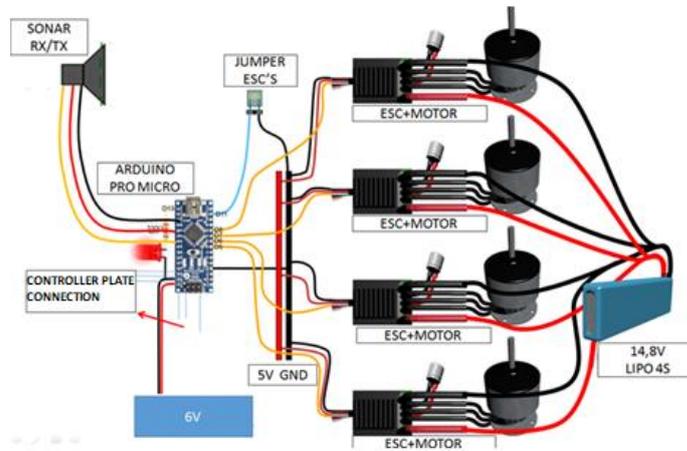

Figure 5. Connection scheme of the aquatic propellers, sonar and Arduino board

3.3 Actuators

The brushless engines were chosen to be used in the aquatic propellers after being tested in order to verify its performance in extreme conditions, as shown in Fig.6. The test was conducted in such conditions in order to verify the saturation and stress of the engine. During the test, the current had a the peak value of 17.3 amperes and 12.1 amperes in the nominal, these conditions agree with the manufacturer recommendations. Therefore, after the series of tests it was stated the submerse operation will not compromise the operation of the engine and will not damage the electric circuits attached on it.
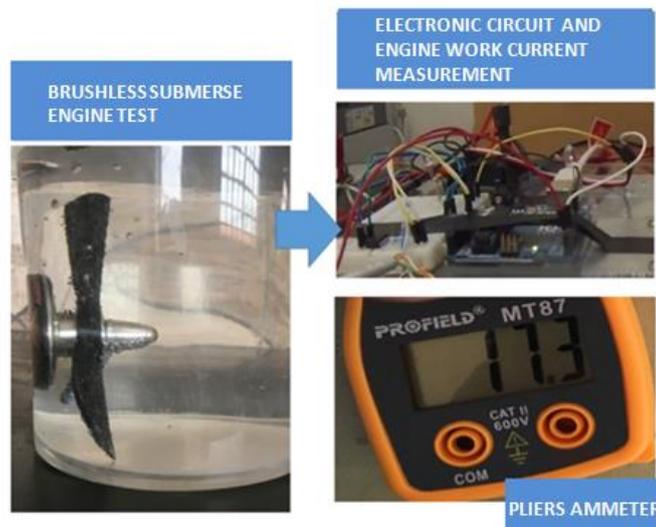
Figure 6. Submerse brushless engine test

3.4 Prototype Finalization

During the initial steps of the construction of the prototype, some parts were found extremely difficult to be manufactured due to its characteristics and shapes. In order to overcome this drawback, 3D printing was used so the parts could be produced in any shape required. The physical model is shown in Fig.7 shows the printed prototype and the accessory parts printed.
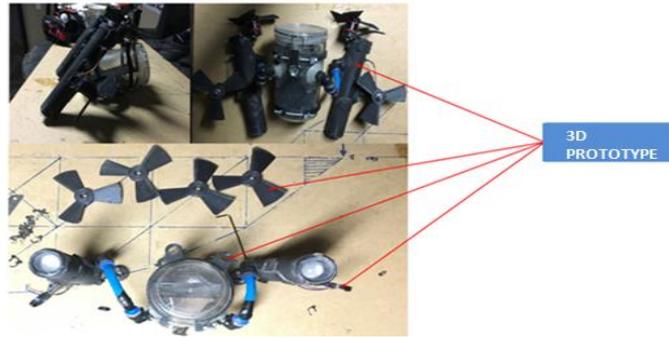
Figure 7. 3D prototyping

For the underwater movement, independent propellers were chosen, as shown in Fig.8. The independent propellers were chosen in order to increase efficiency and the safety when maneuvering underwater and, consequently, to improve the buoyancy in agitated waters.
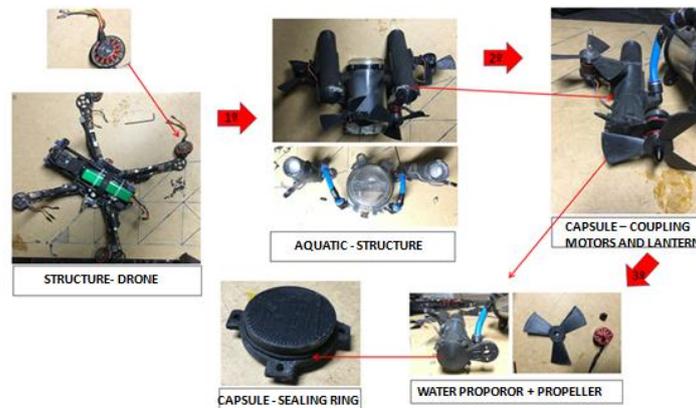
Figure 8. Prototype details

3.5 Software and geoprocessing

The Arduino board along with a flight controller Pixhawk 4, are software platforms which can execute high-end applications, an Open Source Hardware (OSHW) autopilot, for instance, as shown in Fig.9. The OSHW autopilot is available for academic and industrial communities for very reasonable prices. The Pixhawk 4 system, can execute a number of simultaneous tasks without one interfering on the other. These tasks share the same process resources, however, they can be executed independently. Another advantage is the fact that it offers a programming platform that can run on Unix/Linux systems, as shown in Fig.10. The integrated autopilot functions programs with detailed mission logs and flight behavior.

Figure 9. Open Source Hardware

Figure 10. Navigation algorithm between Arduino board/Pixhawk 4

A sonar was attached to the system in order to interact with the flight controller and the Arduino board (when underwater). The sonar sent and received signals on the horizontal direction, with an inclination of 30° from the bottom of the water body. The frequencies obtained are transformed into analog variables which compiles it in a graphic showing the depth of the water, as shown in Fig.11.

Figure 11. Underwater depth graphic obtained with the sonar

After all the steps, the final prototype is illustrated in Fig.12. The proposed objectives were met, showing that the constructed prototype has the required economic feasibility and its implementation can become a beneficial option.

Figure 12. Final prototype

3.6 Communication Interface

In order to explain the prototype communication and controlling functions, a schematic drawing is shown in Fig.13. In the scheme the human-machine interaction is illustrated, showing the drone flying to the drowning location. After reaching the desired location (considering that the prototype is already set up with the necessary information to trace the possible radius of the victim's location), the prototype lands on the water surface while the rotors are turned off. Then,

the aquatic propellers are turned on, and the prototype now dives, and moves in a semi-autonomously way. The device is operated by two people, which are:

- Operator 1: in charge of analyzing the images and commanding the device
- Operator 2: in charge of analyzing all the geographic parameters and data in order to provide Operator 1 with relevant information (real time data)

After the location of the victim, the device goes back to the surface and then flies back to take-off location. Then, the rescue team starts its operations, now with the exact location of the victim and thus, assuring a riskless dive.
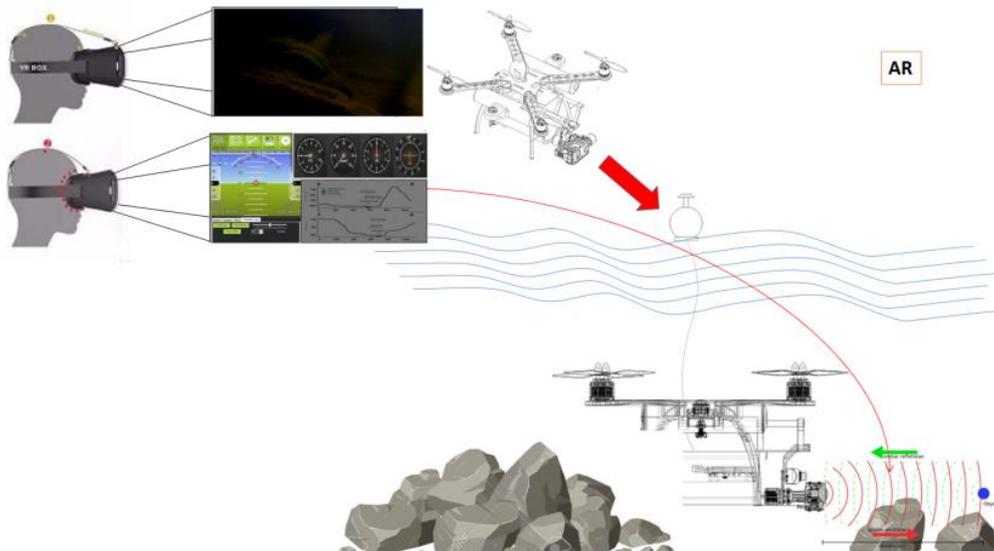

Figure 13. Operation scheme of the device

4. TEST TOPOLOGY

The test was conducted on a river stream located in the city of Varginha, in the state of Minas Gerais, Brazil as shown in Fig.14. The objective of the test was to locate an object in a previously unknown place underwater. Therefore the prototype had to locate the object and inform the exact coordinates of it, in order for its "rescue".
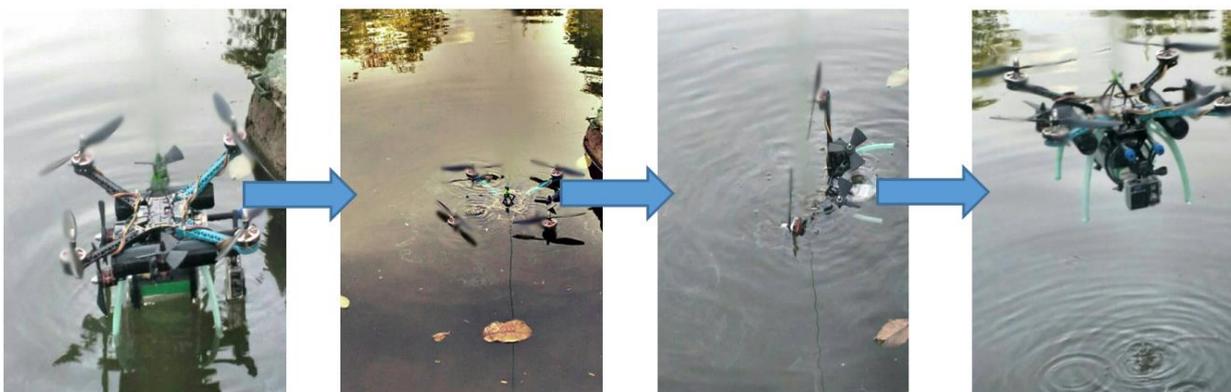

Figure 14. Test Topology

5. QUALITATIVE AND QUANTITATIVE RESULTS EFFECTIVELY MEASURED

During the development of the present research, the construction of the functional prototype was possible. The device behaved as predicted in simulations. The operator needs only a radio controller and an optical device (such as, Google Glass, for example) in order to maneuver the drone, at distance and with aid of real time 3D images, in the exploration of the underwater surroundings. Therefore, the search and rescue of missing people due to drowning in

major events, such as disasters or catastrophes, do not have the need to have big teams exposed to dangerous conditions. Instead, a small team, equipped with the drone can do the same job as a big and complex team of divers. This fact already indicates that the prototype is feasible in civil and military applications. However, more thorough demonstrations are required even though the viability of it is already stated as it is shown in Fig.15.

Figure 15. Validation and Partneship with Varginha (Minas Gerais) Fire Department

Tests were conducted also in the practical area, as it is shown in Fig.16, following the test topology, described in the previous item, in order to show the viability of the execution of search and inspection. The movement controls were conducted through a radio frequency in a Real Physical System (RPS) system simulation. The demonstration was importanto to prove the efficiency of the developed controls which have a friendly and intuitively operation even during critical and delicate tasks such as the search of drowning victims.

Figure 16. Real Physical System (RPS) system simulation

The following items explain the problems and the proposed sultions about the usage of the submersible drone:

- Problem: A search and rescue group was trying to locate missing people in blurred and turbulent water. Consequence: two rescue divers from 5° GBM dived until a 4 m depth, with 1,5 m of visibility in order to locate the victims. However, one of the rescue divers died after being washed away with the current.
- Solution: with the usage of the prototype, the search could be held continuously and without risking the rescue divers lives probably avoiding a possible death since the professional would not enter the water until the exact location of the victim is known and the surroundings mapped.

6. CONCLUSION

This study can be considered an innovation due to the fact that it presents a submersible drone prototype. The device was validated with professionals from the Fire Department of Varginha (Minas Gerais), such as colonels, commanders and chief of diving and aviation team. The drone was projected for long haul flights including submersion, allowing it to move underwater while being controlled by an operator via radio frequency and, thus, releasing the professional from being present at the incident location in the first moment. Through the attached camera, which broadcasts real time images to the operator, drowning victims can be located without the presence of human divers, creating advantages in the operational costs and safety of the rescue teams. The drone can provide a new pattern in search and rescue of missing victims, providing agility in the search maneuvers.

Despite being considered a simple innovation, the device is under patent number BR 20 2017 006685 7, making it possible to prove that it implementation can provide a secure operation for the professionals involved and in the exploration of harsh environments without exposing humans to any risk. The colonel and the lieutenant from the firemen of Varginha (Minas Gerais) requested multiple times the participation of the author in the maneuvers conducted with the prototype.

7. REFERENCES

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8. RESPONSIBILITY NOTICE

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