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### **Marine robots: Applications in marine archeology**

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### **Abstract**

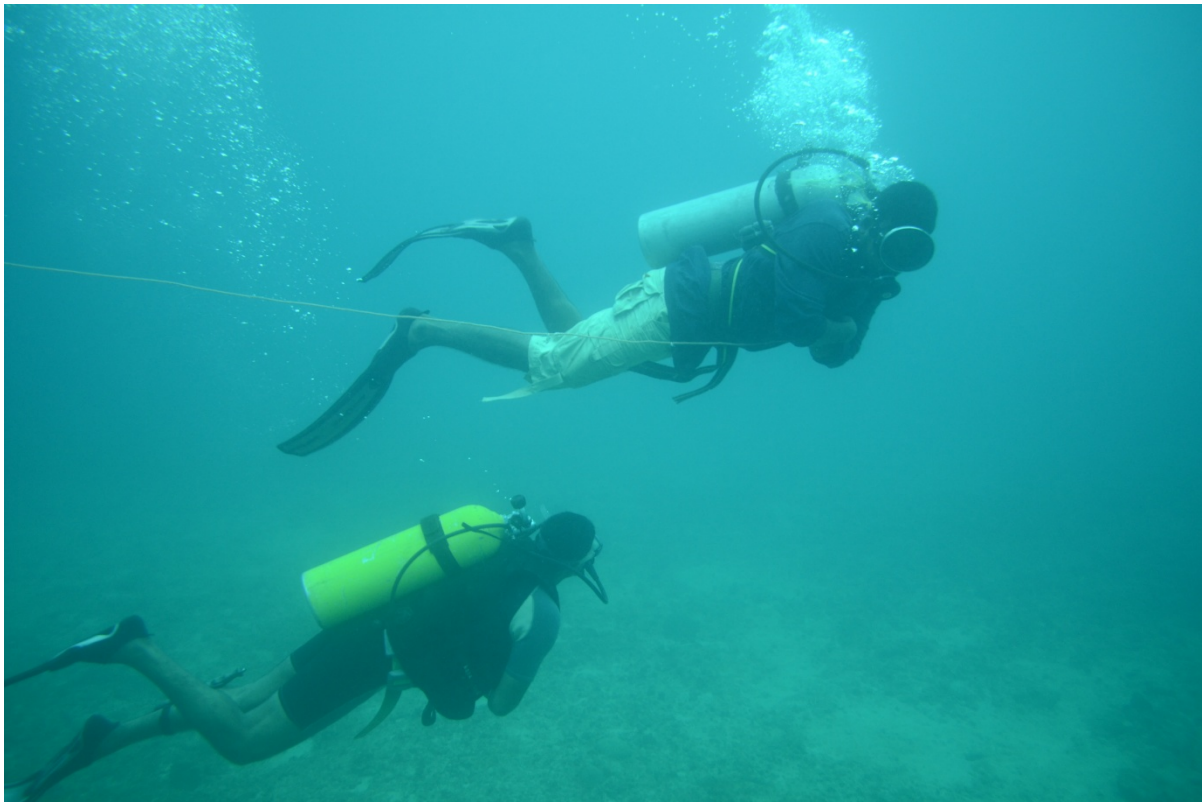
*This article explains how underwater robots have the potential to become companions (buddies) to divers, effectively assisting them by carrying tools and instrumentation and taking high resolution images under the commands of the divers. These robots can also guide divers to move to safe locations in case distress situations occur. However, humans are by nature curious and will never agree to have their eyes completely replaced by robot eyes. The article also explains how a single robot was used in Grande Islands of Goa to photograph the coral reefs.*

### **Introduction**

Recent technological developments in new sensors, memories, embedded controllers, and materials have brought in a new generation of miniaturized ocean data collection platforms of which Autonomous Underwater Vehicles (AUVs) and Remotely operable vehicles (ROVs) are representative example (Elgar Desa, R. Madhan and P. Maurya, 2006). The development of underwater robots has afforded the community a new set of underwater “eyes” to assess the health of our surrounding waters and carry out studies of underwater ship wrecks, coral reefs and marine diversity, etc. However, humans are by nature curious and will never agree to have their eyes completely replaced by robot eyes.

Often, underwater archeological activities require carrying out measurements, collecting samples, and taking photographs or videos of the environment. Under the harsh conditions imposed by currents

and low visibility. Divers often use conventional tools and aids which are not sophisticated and cause hindrance in their activities. Representative examples of such tools can be found in (Underwater Archaeology of Dwarka and Somnath(1997-2002), 2008). Figure 1 shows that a diver is tied to a rope which is attached to the boat which restricts the motion of the diver and limits his reach for excavation of the place.



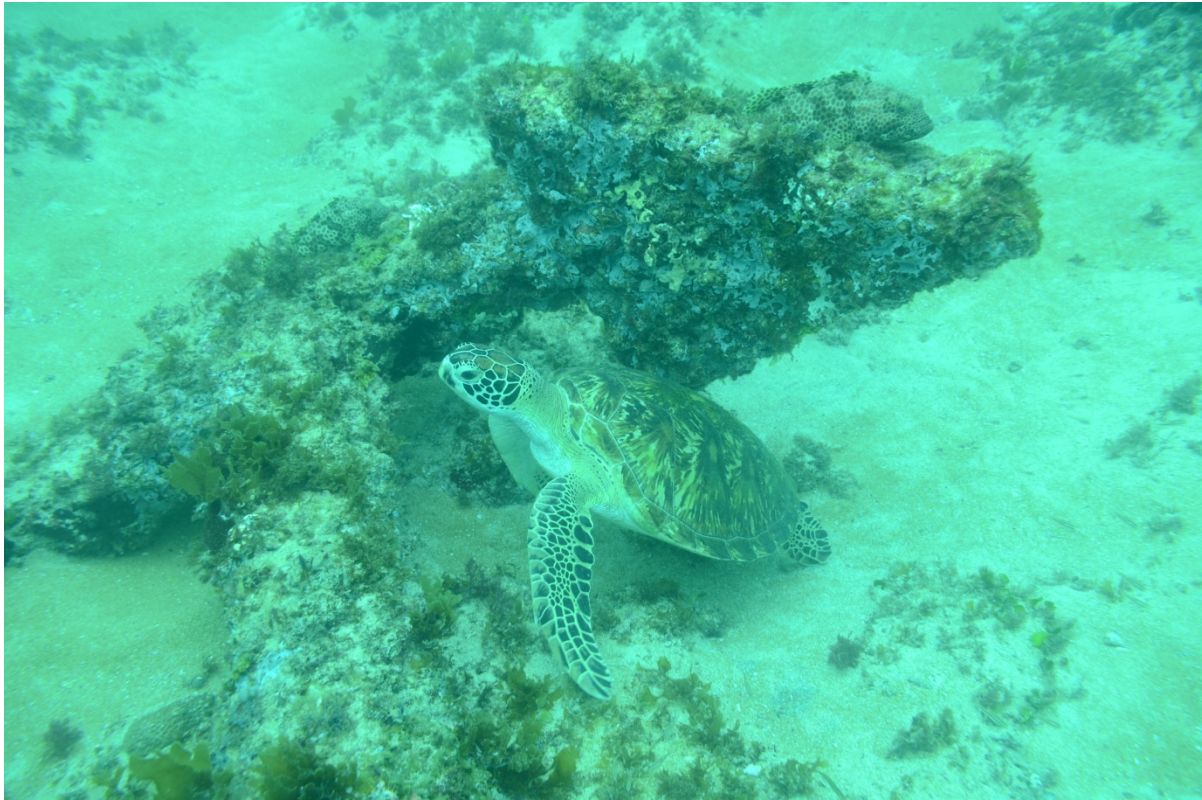
**Figure 1. Restricted movement of the diver. (Source : Marine Archaeology, NIO, Goa)**

The human eyes are adapted for viewing in air moreover the visibility underwater is lower than in air and many objects appear blurred. Certain places may have extremely low visibility (lower than normal) which can add to the predicaments of the diver underwater (See Figure 2).



**Figure 2 Area of operation with low visibility. (Source : Marine Archaeology, NIO, Goa)**

At times a diver may drift away from his path due to lack of guidance system and the beautiful marine life may divert the attention of the diver. *Figure 3* shows a diver misses out an artifact (anchor of a ship) during one the archeological exploration mission, which was later recognized by careful examination of the video images.



**Figure 3. The diver missed the anchor below the turtle. (Source : Marine Archaeology, NIO, Goa)**

These activities become risky and even life threatening, especially under the harsh conditions imposed by strong currents, low temperatures, and poor visibility as mentioned above. In such situations, divers can get into dangerous distress situations. All these life threatening quandaries must be overcome in order to avoid the risk in underwater diving. In this paper we present a tool for tracking and guiding an underwater diver to assist him to overcome life threatening conditions. The work in the paper is highly motivated with the experiments done at Instituto Superior Tecnico in Lisbon using multiple autonomous underwater vehicles (AUV) named "*Medusa* (Figure 4). Figure 5, shows an artistic view of a typical diver localization and guidance scenario.





Figure 4. Medusas (AUV) floating on the surface of water locating an underwater diver

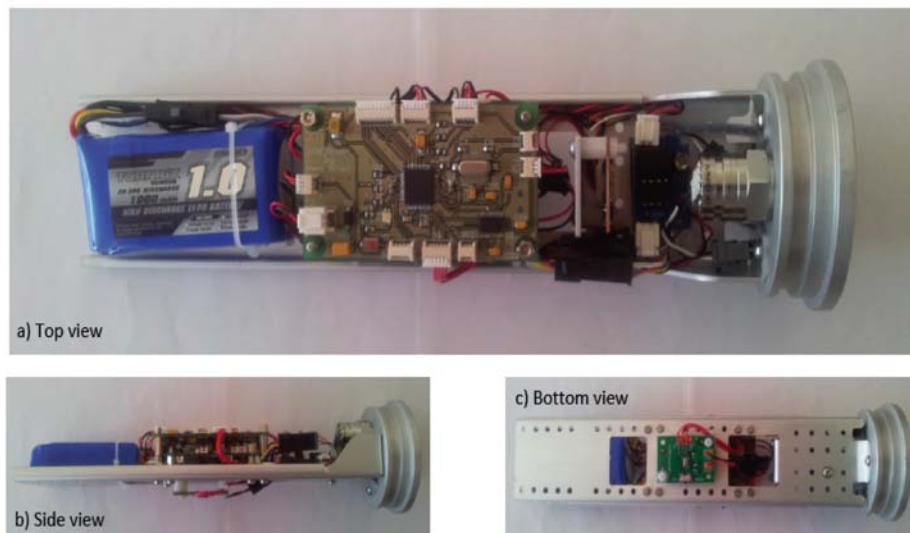


Figure 5. A pictorial view diver tracking and guidance

### Diver Tracking

An underwater diver is equipped with a unit which contains an acoustic modem, battery and a small microcontroller (see Figure 6). There are three robots on the surface each of them equipped with acoustic modems and global positioning system (GPS). One of the robot is designated as reference unit which initiates sending an acoustic signal using its acoustic modem. Other robots start their acoustic modem to listen the reply exactly at the same time. The acoustic signal send by reference unit is

received by the diver unit and diver unit replies with another acoustic signal which is received by all the units on the surface. Using the round trip travel time by the acoustic signal, distances to all the surface units can be computed. The speed of sound in water (typical speed is 1500m/s) is known a priori. The diver unit is also equipped with a depth sensor. The depth of the diver can also be sent along with acoustic signal replied by the diver unit. Borrowing the tools from coordinate geometry position of the diver can now be computed. Each AUV calculates the distance of the diver from itself and the exact position of the diver is determined by drawing three circles of radii equal to the individual distance of the respective AUVs from the diver (See Figure 9). The point where these three circles intersect is the point where the diver is present.



**Figure 6. Unit to be carried by underwater diver**



Figure 7. a. Diver unit mounted on the air supply cylinder, b. Diver taking the unit to dive, c. Preparation for the final test

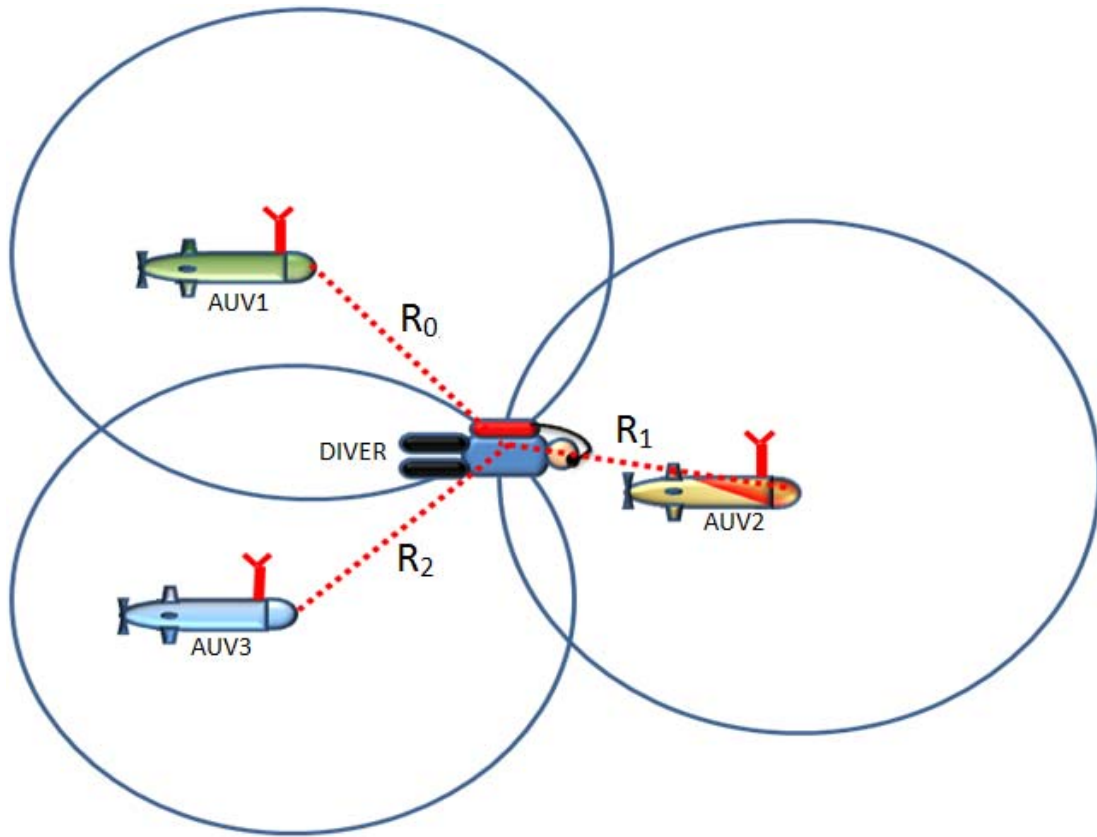


Figure 8. Geometric solution to find diver location



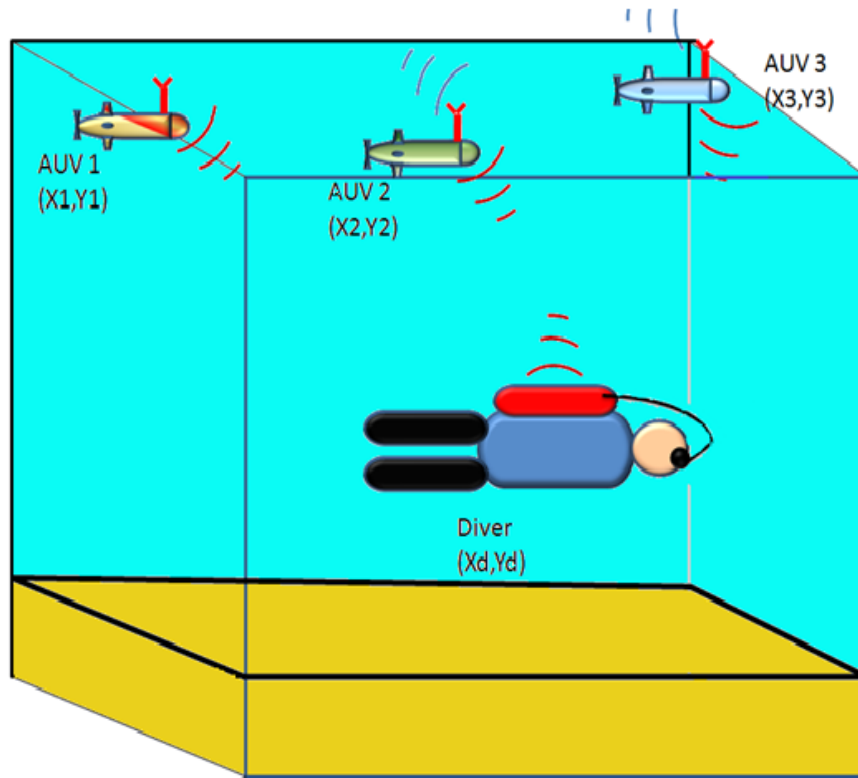


Figure 9. Setup of the AUVs and the diver.

Lets us say the AUV1 is a reference and sends an acoustic ping at time  $t_0$  and the time of reception of the acoustic reply sent by the diver at AUV1 is  $t_1$ , at AUV2 is  $t_2$ , and at AUV3 is  $t_3$ . Thus the distance  $R_0$ ,  $R_1$  and  $R_2$  can be given by,

$$R_0 = \frac{V_s(t_1 - t_0)}{2}$$

$$R_1 = \frac{V_s(t_2 - t_0)}{2}$$

$$R_2 = \frac{V_s(t_3 - t_0)}{2}$$

where  $V_s$  is speed of sound in water. The positions  $(X_1, Y_1)$ ,  $(X_2, Y_2)$  and  $(X_3, Y_3)$  of AUV1 , AUV2 and AUV3 respectively are known using their respective GPS. Using co-ordinate geometry, the distances can be calculated as a function of position of diver  $(X_d, Y_d)$ .

$$R_0^2 = X_d^2 + Y_d^2$$

$$R_1^2 = (X_1 - X_d)^2 + Y_d^2$$

$$R_2^2 = (Y_2 - Y_d)^2 + X_d^2$$

Solving the above equations the diver can be located as following

$$X_d = \frac{X_1^2 + (R_1^2 - R_0^2)}{2X_1}$$

$$Y_d = \frac{Y_2^2 + (R_2^2 - R_0^2)}{2Y_2}$$

Furthermore, a simple filtering algorithm may be used in order to deal with the noises in the measurement and disturbances in the motion of the diver (Thomas Glotzbach, Mohammadreza Bayat, A. Pedro Aguiar, Antonio Pascoal, 2013).

### **Diver Guidance**

In order to guide the diver to move from one point to the other or to guide him to follow a transect underwater, an interaction between robots and the diver is must. After discussing with several divers about possible ways to interact with them while they are underwater, we decided to use light emitting diodes (LEDs) mounted on the mask. A set of green, red and white LEDs are attached to the mask of the diver which are connected to microcontroller of diver unit. Red LEDs indicate turning to right of the diver and green LEDs indicate for turning left. White glows for the diver to go straight. The rate at which these LEDs blinks indicates speed at which the diver needs to turn. A simple path following algorithm (P. Maurya, A. Pedro Aguiar, A. Pascoal, 2009) for the diver guidance is executed on the reference unit which is mounted on one of the robots on surface. The command for the turns are computed by the algorithm and are sent along with the acoustic signal transmitted for locating the diver. The points which diver needs to visit (mission) are known a priori by the diver as well as by the surface robots.

Moreover, in case of distress or emergency diver can press a button on his unit and the robots on surface will abort the mission the and guide the diver to reach a safe location.



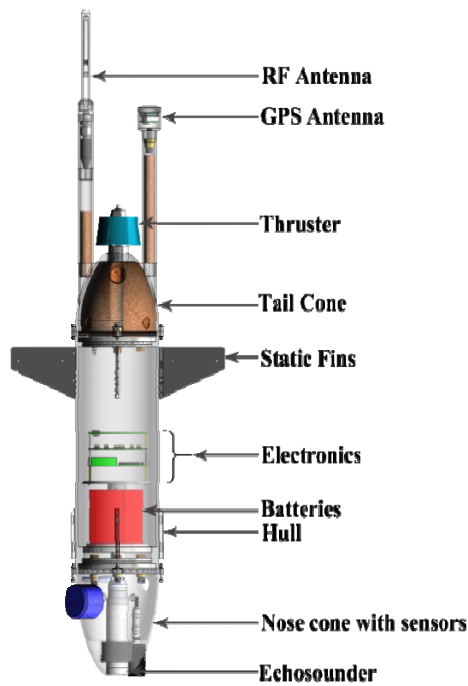
**Figure 10. Diver and robot interaction using LEDs**

### **Coral reef photography**

An autonomous vertical profiler (AVP) developed at National Institute of oceanography was used as a tool to acquire images of coral reefs at Grande island and Bats island in Goa. The AVP is a small robot which is capable of diving vertically into the sea up to the depth of 200m. This robot is also programmed to hover like a helicopter in the water at any given depth. Moreover it can also maintain a certain altitude from the sea bottom using its altitude controller. However, it has no control over its horizontal motion and it drifts with the currents. A schematic of AVP mounted with a *GoPro* camera and strobe lights is shown in

*Figure 11.* Bats Island are located near the shore of of goa at latitude  $15^{\circ}22'27.62'$  N and longitude  $73^{\circ}47'54.38'$  E . We operated the AVP on 19 november 2012 at 0722hrs GMT to acquire images of coral reef. A mission for to maintain an altitude of 1m above the sea bed was executed. Selected photographs taken by AVP is shown in Figure 12 , Figure 13 and Figure 14. Figure 12 shows a picture of a palm coral near bat island. The photograph shown here is processed to enhance the contrast. Figure 13 shows a sequence of photographs taken by AVP while the was maintaining the altitude and drifting over the coral reef.

Figure 14, shows a whip coral in the close by site at Bats island. Advantage of using such a robot for photography over any conventional method is having added information about the environment surrounding the objects. AVP is equipped with chlorophyll, turbidity and CTD sensor along with camera hence, it can record the environmental condition and tag it with the photographs recorded. Figure 15, shows a high turbid water where the images of the coral reef were taken.



(a) schematic of AVP

(b) AVP equipped with camera and strobe lights

Figure 11. A schematic of an autonomous vertical profiler



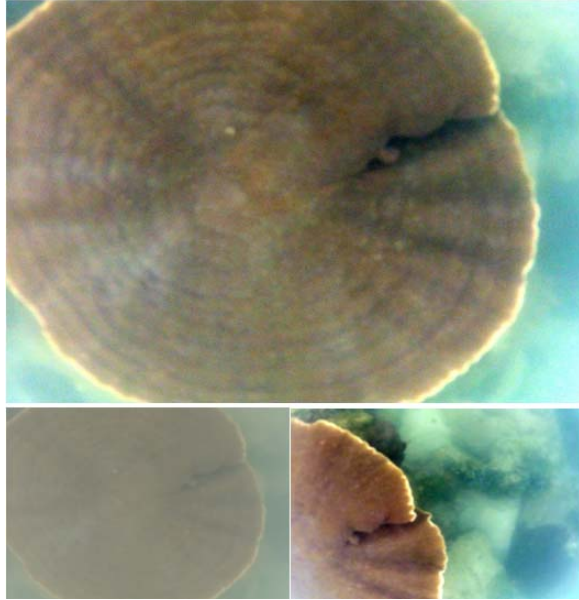


Figure 12. A palm coral photographed by AVP

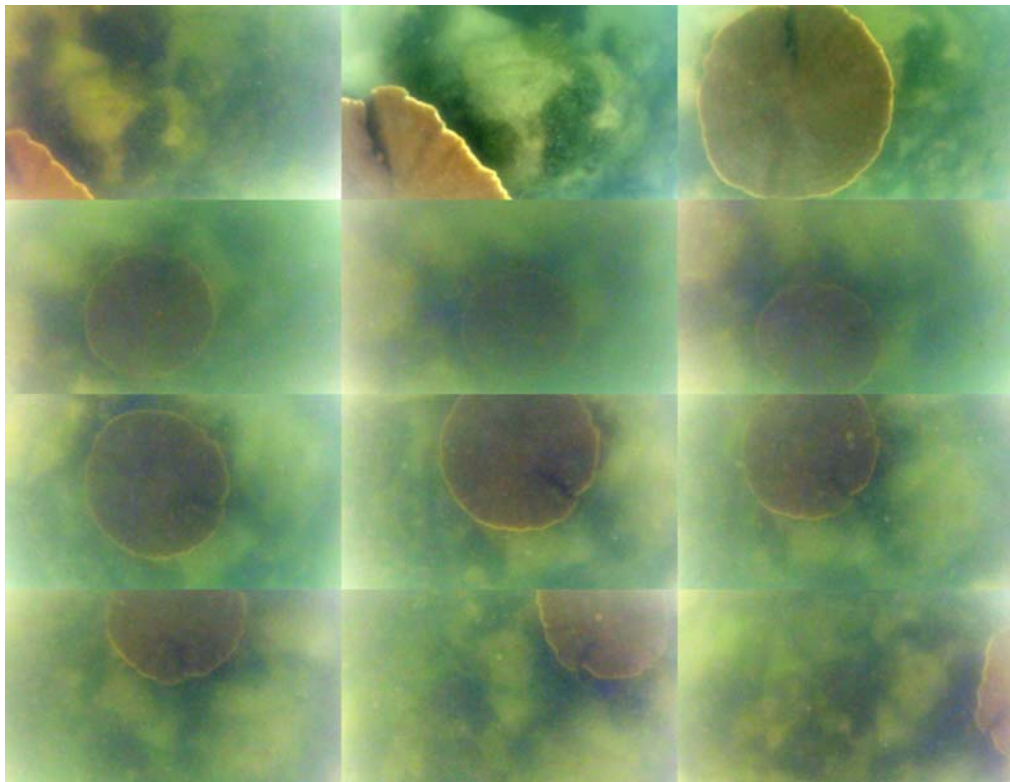


Figure 13. Sequence of pictures taken by AVP while maintaining the altitude and drifting over the coral reef



Figure 14. Whip coral recorded by AVP

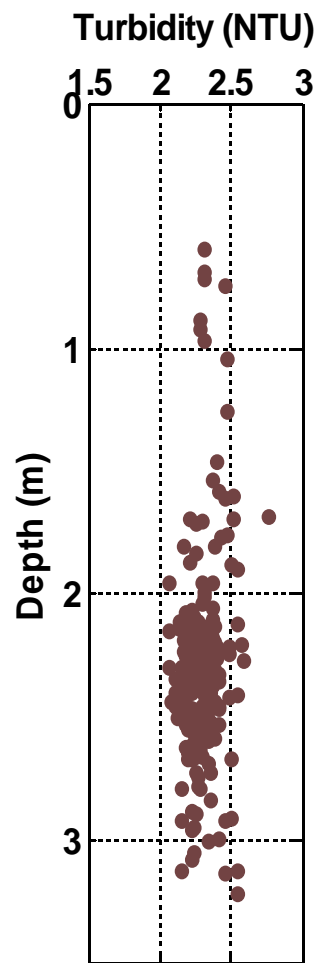


Figure 15. Turbidity profile recorded along with the photographs

## Conclusion

An experiment was conducted in Lisbon, where a diver used the setup described in previous sections to test the diver tracking and guidance system. The test demonstrated the efficacy of the system which enabled diver to successfully complete its mission underwater with almost zero visibility. To test the accuracy of such a system diver was towing a float which was recording its GPS position. The positions estimated by the setup of three *Medusa* was in close match with GPS data with maximum error 5m. However, there is still scope of improvement in such system before it can be easily used by archaeologists without engineering background. The AVP has been extensively used for recording scientific data in sea. The test at Grande and Bats Island was the first attempt to use it for photography purpose. These test demonstrated the use of AVP in waters as shallow as 3 m and as deep as 200m. In summary, marine robots have a high potential to enhance the capability of marine archaeology by becoming companions (buddies) to divers and help in exploration and excavation of archaeology sites in the sea.

## Bibliography

- Elgar Desa, R. Madhan and P. Maurya. (2006). Potential of autonomous underwater vehicles as new generation ocean data platforms. *90* (9).
- P. Maurya, A. Pedro Aguiar, A. Pascoal. (2009). Marine Vehicle Path Following Using Inner-Outer Loop Control. *Maneuvering and Control of Marine crafts 2009*. Guaruja, Brasil: IFAC.
- Thomas Glotzbach, Mohammadreza Bayat, A. Pedro Aguiar, Antonio Pascoal. (2013). An Underwater Acoustic Localisation System for Assisted Human Diving. *Maneuvering and control of marine crafts*.
- Underwater Archaeology of Dwarka and Somnath(1997-2002)*. (2008). National Institute of Oceanography, Goa.