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Effect of Low-Frequency Noise on Humpback Whale Behaviors

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Abstract

This paper investigates the effects of low frequencies (20Hz-80Hz) signals on whales' behavior in their natural environment, the purpose being to investigate the probable link of such frequency waves on their collisions with watercrafts, and their grounding. To this aim, the sounds produced by whales to communicate between them were first recorded using an autonomous underwater vehicle designed, fabricated and successfully tested by the authors. Then, a series of tests were conducted, which demonstrated that, indeed, low frequencies can dramatically perturb the ability of whales to detect and circumvent obstacles, as well as to properly find a safe pathway.

Keywords: AUV; Low frequency; Humpback whale (*Megaptera novaeangliae*); Dolphins (Porpoise); Whale stranding; Persian Gulf; Gulf of Oman

Introduction

In the recent years, intensive researches have been performed to gain a clearer understanding of the causes behind the collisions of whales with watercrafts and their grounding. However, even if many theories have been broached regarding this issue, the challenge is still open.

In this work, different tests were conducted to better understand the behavior of whales while facing low-frequency annoying noises. They demonstrated that whales indeed favor the communication between them through signals. Therefore, superposing noise signals, in the frequency sound of 20 to 80 Hz, to their own emitting/receiving signals indubitably perturbed their sense of orientation and the effect such noise may affect marine life, sea mammals and fish [1].

System Description

We first designed an Autonomous Underwater Vehicle (AUV) based on the motion of the white sided dolphins [2-4].

Robot body

To successfully design the robot body, one should first establish a primary plan of the body structure with the location of each sub-part, knowing that the device will be made of one piece with a camera on the top and engines attached on the sides. In this work, the robot's shape has been inspired by the dolphin's body (Figures 1 and 2). Note that with this form, the whole set will be naturally balanced by using a Mass Shifter (MS) unit incorporated in the body that should be put "on" at the same time to create a simultaneous vertical-horizontal movement, a pair of mobile thrusters was designed to save the power supplied by embedded batteries. In practice, the two thrusters shown in Figure 1 could be oriented within a specific angle based on the vertical and horizontal forces required to move the device in a predefined direction. Any change in the thruster angle should be made possible by the instant movement of a servomotor, which consumes much less energy than the constant movement of a fixed thruster.

Robot functional structure

In the embedded mini-PC motherboard, a serial port has been dedicated to the top rotating camera, while the two other cameras, the sensor board, and the transceiver module have been connected to USB ports (Figure 3). Note that the sensor board is a two-level board with compass, pressure, temperature/humidity, IMU, and heat sensors. Based on the data collected by the cameras and the different sensors, the mini-PC sends commands to the thrusters via an engine driver card (Figure 4).

Preliminary Tests and Research Motivations

Many tests were conducted to evaluate the performance of the designed robot in both Pacific and India oceans. These regions have been retained because the motivations behind the design and fabrication of the robot were to study the humpback whales' behavior in their real environment. Preliminary tests were carried out to investigate their motion, vision capabilities, and decision-making as a group and/or as individuals. The first point we noted is that the whales can detect the presence of dolphins, their preys, over long distances. This gives them enough room to prepare for proper movement and maneuverability due to their large size. As highlighted in previous studies, humpback whales (Megaptera novaeangliae)' sight is only about 10 meters, and the presence of storms, weather changes, and water pollution can make their eyesight even weaker. Therefore, they should use signals to guide themselves and detect obstacles and potential preys, within a few miles of distance [5,6].

They are, in fact, ready for hunting before reaching their targets. From that, it will be of high interest to analyze the whale dynamics according to the signals they transmit/receive.

In this work, we used a microphone located on the side of the robot and connected to the embedded robot Mini-PC through the sensor board (Figure 5).

Humpback Whales: Existing Knowledge

According to whales' specialists, the humpback whales size/weight can vary from about 2 m/180 kg (Dwarf Sperm whales) to 30 m/170

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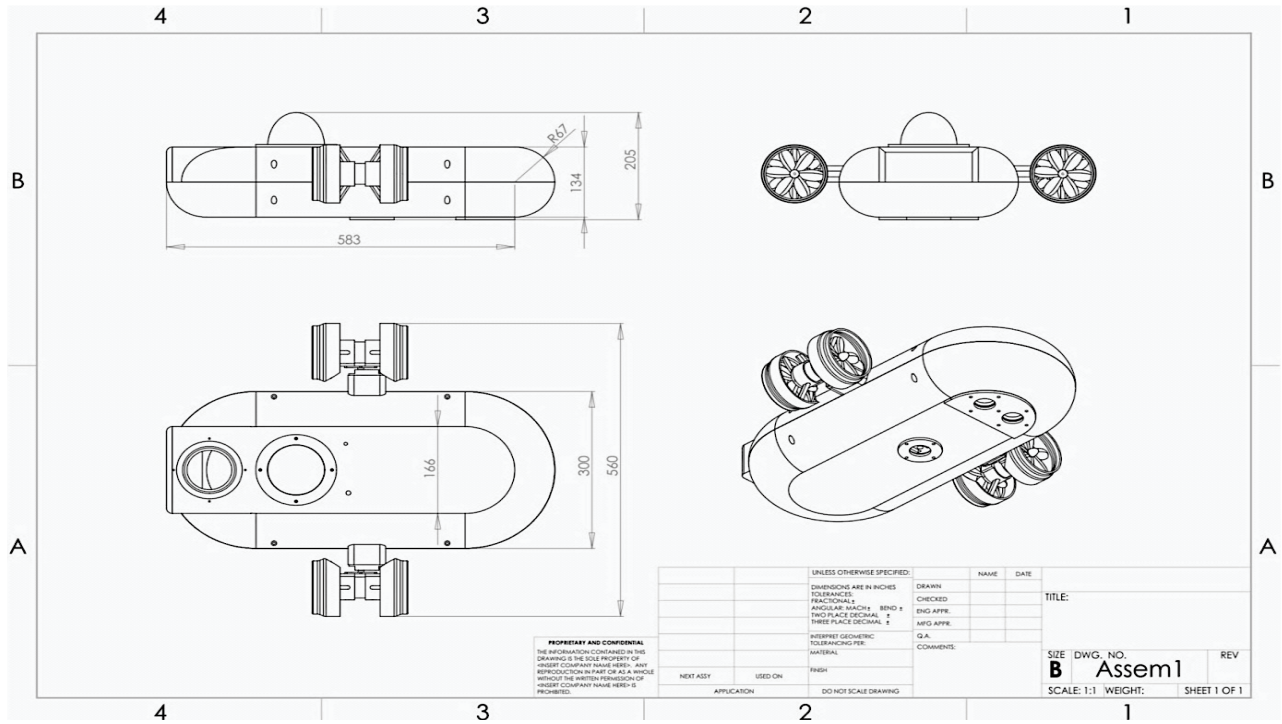

Figure 1: Isometric scheme of the designed robot.

Figure 2: Different views of the designed robot in operation.

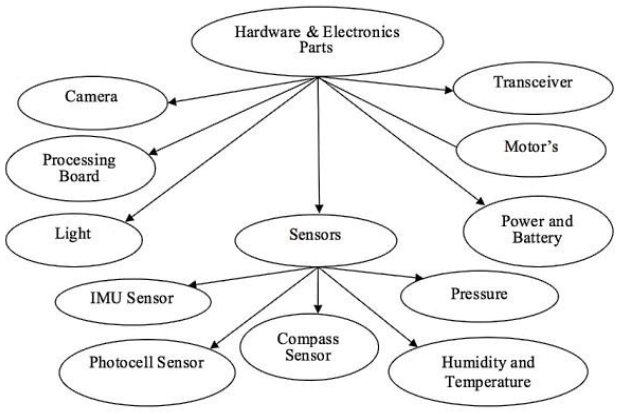

Figure 3: Electrical parts.

Tons (Blue whales). They are placentalia species of marine mammals, which are of two main types namely, Baleen whales and Toothed whales. Baleen whales have a very strong odor potential, while Toothed whales have very good hearing abilities. These whales, even if they are blind, can survive by efficiently use their hearing [7].

Unfortunately, their number is dramatically decreasing because they are at risk from other environmental hazards such as marine pollution or hunting. Stranding is also one of the major causes of their decline, as detailed below.

Whale Stranding

Cetacean stranding, or beaching, is a phenomenon in which whales and dolphins strand themselves on a beach, thus leading to their death due to dehydration, collapsing under their own heavy weight, or drowning when high tide covers the blowhole. The reason behind this phenomenon is still unknown, but there are various working hypotheses presented to address this issue. A first theory favors the fact

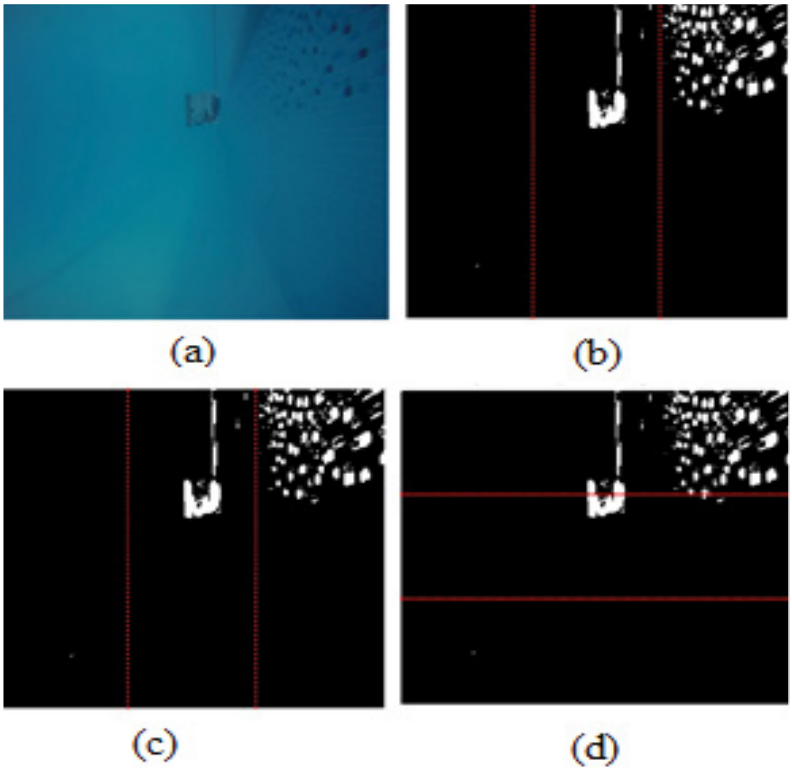

Figure 4: An example of image scoring system. The original image (a) is subdivided into six sections (b), i.e., three vertical bands (c) and three horizontal bands (d).

Figure 5: Designed robot with the microphone on the side.

that these animals go into shallow waters by mistake or if they are ill guided by their group leader and then, if they encounter an adverse combination of tidal flow and seabed topography, the larger and heavier species can become trapped. A second theory is that old whales sometimes do not have the ability to compete with younger fellows, leading to less food resources. They, therefore, go to the shallow areas to find enough food. However, the opponents of this theory claim that the number of young individuals that strand is still high, and there are frequent cases of whale stranding in areas where there is plenty of food - like southern Australia. A third theory is a possible role of a virus inside the stranding event. However, no specific disease has been highlighted among beached whales [8].

On the other hand, researchers from the University of California examined data sent from electronic clips attached to unicorn whales (marlins) and found that the heart rate of this aquarium will lower in the presence of a danger, but at the same time, they have to swim quickly to escape it. These researchers said that the response of the unicorn whale is "very costly" because, during its intense activity to escape, the oxygen that reaches its brain is limited. When the whale is running at full speed and its heart rate is so low, it may not give enough oxygen to the brain and the whale will lose its direction and path. If this decline in blood flow and the lack of oxygen to the brain continues for a long time, it can even cause permanent damages to the brain [9]. “Suicides” annually kill about 2,000 sea creatures [10].

Aram Group Research in the Persian Gulf

The Aram group is a small independent group of volunteers that perform research about the environment of the Persian Gulf and Gulf of Oman because, unfortunately, various mammal species in in these areas are endangered and harmed. The Persian Gulf is one of the largest marine sanctuaries with coral, small fishes, edible and non-edible fishes, shellfishes, snails, clams, marine snows, sea sponges, sea brides, turtles, dolphins, sharks, and many other sea creatures [11]. The group began its research after receiving many reports on the collision of whales and dolphins with floats and their grounding. In the present work, investigations were conducted during a total of 16 months spread over several periods (July-November 2015, March-August 2016, October-November 2017, and May-July 2018) in places where the whales and dolphins were reported to be flooded and landed.

The following stranded carcasses were identified:

1. Carcass of a 13m whale on the shores of Asaluyeh, wasted as a result of a collision with the blade of a float in the Pacific Ocean.

2. Carcass of a 10 m whale on one of the beaches near the Kandaloo Qeshm Island.
3. Carcass of a 14 m whale around the beaches of the village of Lilitin, Bandar Deylam.
4. Carcass of a 12 m whale weighed of about 10 tons between the ports of Gerzeh and Bandar-e Tauneh of Bandar Lengeh.

Research Summary

1. The collected data included water temperature, pollution, and depth, type of animal species, ship motion program, existence of transmitter and receiver antennas in the area as well as human demography in the targeted areas.
2. The high level of pollution of the region, mainly due to boats as well as urban and municipal sewages, has been well documented in all the studies carried out along the path of whales, but it looks from our observations, that the number of collisions/strandings is not directly related to the level of pollution.
3. Also, whales are not hunted in the Persian Gulf because of the beliefs of the indigenous people, and they do not threaten, except for collisions with boats. Most of the whale carcasses discovered had signs of collision with floats, which increases the hypothesis of floating disintegration and then suffocation and death.
4. Furthermore, the demographic tissue in the region is diffusely distributed and there are uncultivated and inhabited areas in the places where strandings have been reported.
5. Nevertheless, during this study performed by the Aram group on a triple group of humpback whales, it was initially noticed a change in the behavior of different whales near local floats and tankers. Also, the behavior of whales showed that they may be able to detect the type of float, since they show different reactions while facing boats of different shapes. Since this cannot be due to their weak sight ability, the hypothesis could be because of the sounds produced by the boats and/or vibrations of the various floating engines present in the vicinity of the whales.
6. To further investigate this approach, the sound of a diesel engine Caterpillar 1200 HP was recorded by a 12m Launch during 30 minutes. After filtering the undesirable surrounding noises, it was broadcasted to a group of three humpback whales and six dolphins as well as a solitary humpback whale using a 3.5 m boat when the boat engine was off. By broadcasting this engine sound, we observed that after 8 mn and 5 mn, respectively, the group of humpback whales and the group of dolphins came back to their normal behavior. They even came close to the boat from which the sound was diffused in the ocean.

1. In a second experiment, three different types of sounds from local ship engines were recorded, i.e., engine E1 (Doosan 1200 HP), engine E2 (Yanmar 500 kW), and engine E3 (Mitsubishi 640 kW), along with a completely different sound from an agricultural tractor engine. The obtained results can be summarized as follows for the whales:
2. The reaction of the group of whales to the engine E1 was in line with the previous test.
3. As for the sounds of engines E2 and E3, the whales settled down after about 3 mn.
4. Regarding the tractor engine, at the time we started diffusing its sound, the whales went away.
5. As regards to the group of dolphins (Porpoise),
6. The reaction of the dolphin group to the engine E1 was in line with the previous test.
7. We observed no specific reactions when the sounds of engine E2 and E3 were played.
8. They showed disturbance and fear when hearing the sound of the tractor, thus quickly running away.
9. Because the area under study belongs to a quite sensitive region, it was very difficult and sometimes impossible for the Aram group to detect the frequency bands transmitted/received in the area. However, they realized that within the period of white sided dolphins' grounding and landing, low frequency signals of 50-60 Hz were detected, for sometimes more than 14 hours on specific days. Note that these signals were transmitted for more than 36 times (18 times for more than 2h without interruption), knowing that Extra Low Frequencies of 50 to 80 Hz are potentially hazardous. In fact, studies showed that exposition to such frequencies can result in painful shock and severe cardiovascular and respiratory problems, and even can induce chromosomal damage [12,13].

Generating Annoying Frequencies and its Results on Humpback Whales

According to the above observations, the Aram team diffused pulse signals at 20, 50 and 60 Hz in places where whale and dolphin strandings and collisions with boats have been reported in the past that all of the tests were conducted under the supervision of a veterinarian and an animal psychology.

In the first experiment, annoying pulses of 20, 50 and 60 Hz were broadcasted to a group of six humpback whales as well as to a solitary individual at various intervals (i.e., 8, 15 and 20 mn) and distances (i.e., 60, 30, 15 meters). As reaction, all whales showed nervousness and increased breathing. So, we decided to end this test to avoid harming them.

The next set of experiments consisted to sequentially broadcast, during 20 mn, pulses of 50 and 60 Hz (8 seconds duration each). When the pulse source, placed at a distance of 21 m, started emitting, the number of signals received from male whales increased dramatically as well as their mobility, leading to the following observations:

1. After several minutes of swimming underwater, the group of humpback whales returned to the surface, while significantly increasing the number of airing by a factor of two to three. Similarly, for the solitary one.
2. An issue of getting enough oxygen was observed in all whales due to the increase in the number and speed of their airing.
3. As group, they were not able to coordinate their movement, and moved to shallow waters with even a collision with one of the transmitters mounted outside a boat.
4. It was noted that one of the whales led the group to shallow areas, increasing the possibility of grounding.
5. These whale movements continued for a few minutes after

the transmitter was completely turned off, which could be an explanation for backing whales to coast after they were returned to the sea.

By generating an annoying pulse at a distance of 500 m in the pathway of the whales, the second experiment well illustrated the fact that whales use signals to communicate in the group. In fact, before the annoying pulse was turned on, the whales were able to easily detect and successfully pass artificial obstacles put in their way. Their reaction was exactly the inverse when the pulse was turned on. Their ability to detect and circumvent obstacles decreased dramatically.

Conclusion

The sound produced by humpback whales, which is distributed solely by male whales in water, after encountering obstacles may give them the ability to analyze the environment. This ability allows them to instinctively estimate the distance and size of an obstacle or the presence of food and even the depth of water, which enables them to recognize and scan the vast environment of their surroundings.

These sounds, created by male whales, can be received by all whales. When sent through water, their state can change after encountering obstacles in the path. Thus, when they reach the whales, the later will have an adequate recognition of their surroundings by analyzing the received sound, and the sending quality of these sounds is one of the driving for choosing pairs at mating time by female whales.

In research conducted on behavior of whales, it was shown that these sounds have limited feedback to younger whales, while analyzing the sounds of older whales gives them more detailed information about the environment. During our experiments, we observed that the ability of the whales to recognize the environment can be reduced or can be eliminated by entering a 20 Hz noise for 16 mn. At that time, wrong moves or collisions were well visible, and in a particular case, they moved to the beach, justifying the possibility of beaching or whales stranding.

The research also showed that collision of ship with whales and even whale suicide could be due to the noise generated in water for an excessive allowed period of time and creation of computational error for whales.

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