CAPÍTULO 1

PROTOTYPE OF AUTONOMOUS RESCUE DIVING DEVICE IN TURBID WATERS

Data de submissão: 22/10/2024 *Data de aceite: 01/11/2024*

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ABSTRACT – Development of a prototype (Autonomous Rescue Diving Aid Sensor in Murky Waters) aimed at being used as a safety tool for rescue dives in the Western Amazon, utilizing electronic components and compatible programming language.
KEYWORDS: Sensor, Diving Aid, Murky Waters in the Western Amazon.

PROTÓTIPO DE DISPOSITIVO DE MERGULHO DE RESGATE AUTÔNOMO EM ÁGUAS TURVAS

RESUMO – O capítulo do livro apresenta o desenvolvimento de um protótipo (Sensor de Auxílio ao Mergulho de Resgate Autônomo em Águas Turvas) com a finalidade de ser utilizado como uma ferramenta de

segurança para mergulhos de resgate na Amazônia, utilizando componentes eletrônicos e linguagem de programação compatível.

PALAVRAS-CHAVE: Sensor, Auxílio ao mergulho, Águas turvas. Amazônia.

1 I INTRODUCTION

The present work shows the difficulties and characteristics of diving in murky waters, considering that diving throughout its evolution has been developing equipment which has increasingly enabled the diver to reach greater depths with greater safety. The rescue dive at CBMRO (Military Fire Department of the State of Rondônia) is carried out in waters with little or no visibility, such as the Madeira River, the largest tributary of the Amazon River and which bathes Porto Velho, Rondônia, Western Amazon.

CBMRO trains its divers through a CMAUT specialization course (scuba diving course), which in today's reality uses diving equipment which does not require the diver to visually monitor its depth and the amount of gas available in its independent diving cylinder (without external means of gas supply using gas supply stored inside the cylinders), without visualizing these instruments that are depth gauges (measures the current depth of the dive) and pressure gauge (pressure inside the cylinders that are converted to dive time limit), the diver is at the mercy of unreliable techniques of safety parameters to perform his rescue dive, and he may run out of gas inside his cylinders and go into apnea (absence of air in the lungs), at any time.

The technical and scientific relevance of the creation of an autonomous rescue diving aid device in murky waters is evident, which will provide the diver with the monitoring of his diving depth limit (diving depth limit is directly proportional to the gas consumption of the cylinders, that is, the deeper the dive, the greater the gas consumption) through vibration sensors, since it will not have visibility of these conventional instruments. The monometer and depth meter, makes the rescue dive safe.

2 I METHODOLOGY

Experimental research was used, which essentially consists of determining an object of study, selecting the variables capable of influencing it and defining the forms of control and observation of the effects that the variable produces on the object.

After an analysis of the problem of the theme, research on the Madeira River began, to know its peculiarities and characteristics that could use a device that worked perfectly in these conditions, with these data, the search for a sensor that met the required needs was started, a manufacturing company was found that made the sensor according to the required parameters, The Holykell company. In this way, we started to assemble the circuit on the protoboard and we started the code, in the first tests, a buzzer was used as an indicator of sensor functionality, so every time the sensor was activated, the buzzer rang.

After the circuit and code were working, the prototype was field tested as it was still necessary to calibrate the sensor in the code.

With everything going as expected in the field tests, the circuit was assembled on the printed board.

3 I DEVELOPMENT

3.1 Evolution of diving and its equipment

The sea, encompassing and cutting continents, occupying two-thirds of the earth's surface with depths of the most varied reaching 11,000 meters (Mariana Trench - Pacific), which would allow you to immerse the highest peak in the world - Mount Everest with 8,845 meters. With its abundant fauna and flora, it is characterized as a good source of food, work and leisure, it has influenced the life of man in an important way, since the most remote times of his existence.

Archaeological discoveries show evidence that man's first contact with the aquatic environment took place in prehistory, probably in the Paleolithic period. Man used wooden harpoons to hunt fish that were part of his diet, as proven by the finds of inscriptions and skeletons ornamented with marine objects found in caves that were inhabited at that time.

The Cretan civilization (3,000 to 1,400 years BC) used the sea as the main source of its economy.

References to the first dives date back to a few hundred years before Christ, with sponge and mollusk fishermen. During some wars, already at that time, there were divers with rudimentary equipment or without it, who sabotaged enemy vessels. In Homer's Iliads (750 B.C.), there are mentions of divers who fished in the sea by diving with harpoons.

A Greek story, related by Herodotus (460 BCE) involves a warrior who fought in the naval wars. Silas, who was a popular Greek, was considered a hero for his brilliant performance in capturing Persians under Xerxes and forcing them to work aboard his ships. It is said that the Persians planned a surprise attack on the Greek ship Artemisium, and during the night, Silas jumped by means of cables to the Persian ship surrendering all the crew members. The story goes that he swam a great distance underwater until he hit a Persian ship. He was considered a hero of that time.

Certainly the first underwater breathing apparatus was devised in 900 BC by the Assyrians. It consisted of an air pocket attached by straps to the diver's body and connected to his mouth through a tube. It was probably made of leather. Some scholars think it was used as a buoy, others as a diving implement.

Figure 1: First underwater breathing apparatus by the Assyrians

Source: Army Diving Course Manual, 2012

Leonardo da Vinci devised some types of underwater breathing apparatus. Most of them had in common a tube that connected the diver to the surface. He also designed diving costumes, masks and helmets. These inventions were unsuccessful, but they served as the basis for the advent of other technically feasible devices.

Probably, the first closed-circuit device was devised by the Italian astronomer and mathematics professor, Giovanni Borelli, in 1680. This device basically consisted of a large air pocket, with a glass window in its front part, which housed the diver's head. The air in the bag was breathed, but it did not pass through any kind of filter, which led to a major inconvenience, the rapid and progressive increase in the concentration of carbon dioxide in the bag of the device, making it unviable. In addition to the air pocket, the diver drove a cylinder with a piston in order to adjust his balance in the water.

In 1715, the Englishman John Lethbridge devised a type of rigid diving suit that consisted of a wooden cylinder, similar to a barrel, sealed.

The diver entered through a hatch located in the front of the device and lodged himself lying on his stomach. There were two holes for the placement of the upper limbs, which were on the outside of the device, and a porthole to allow the visualization of the underwater environment. It was supplied with air through a bellows located on the surface. There are reports that his device would have reached a depth of 20 meters and even carried out several successful works.

Based on Lethbridge's rigid diving suit, Fréminet (1772) and Kingert (1797) developed other types of rigid diving suits, which allowed greater mobility to the diver, as the legs were free allowing the diver to walk on the bottom, but maintained the same characteristic of Lethbridge's diving suit - the dependence on an air source on the surface.

In 1808, Yon Freiderich Drieberg, invented the Triton, a bellows device in a box attached to the diver's back by means of straps, which supplied compressed air to the diver. The greatest contribution of this invention was to show that compressed air could be used to breathe in water.

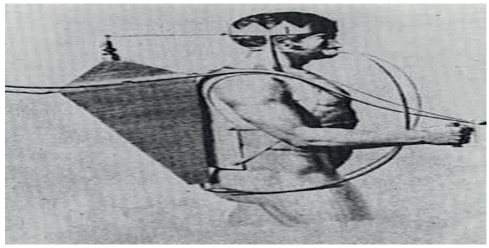

Figure 2: Triton, a bellows device in a box attached to the diver's back

Source: Army Diving Course Manual, 2012

In 1819, the German Augustus Siebe, founder of Siebe Gorman & Co. of London, perfected the existing open helmet, adapting it to a suit that went up to the diver's waist, giving rise to his first open dress, where air entered through the helmet and exited through the waist. This suit had a drawback: if the diver lowered his head or bent the water he could flood the helmet.

Later, in 1837, Siebe developed his closed dress, which consisted of the same helmet as the previous one, adapted to a one-piece, completely watertight suit. The advantage of this type was to provide greater safety to the diver, because if he bent or even turned upside down, he would not present the same danger as the previous one. The Siebe diving suit was widely used, especially in the rescue of the English ship Royal George, which sank in 1782.

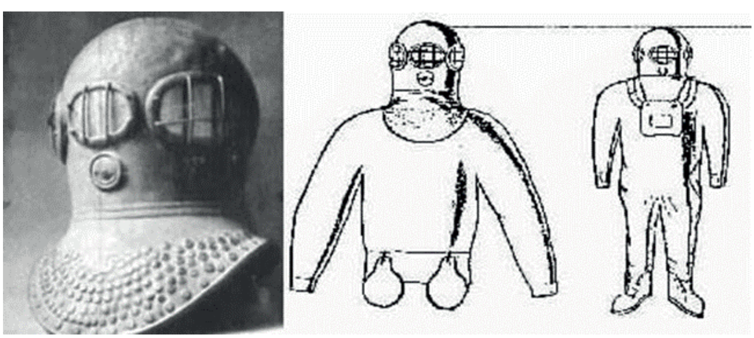

Figure 3: Sieb's diving suit

Source: Army Diving Course Manual, 2012

Later this equipment was improved, with new intake and air exhalation valves, even using a communication system. It is used nowadays only as a hoby, as its use in underwater work is outdated.

A few years later, the first scuba diving equipment appeared in France. Created by Rouquayrol and Denayrouze, this equipment could be used with or without a full-face metal mask. Air could be supplied through a hose from the surface (dependent mode) or, in shorter, shallower dives, carried by the diver himself in small cylinders (autonomous mode). Although the first prototype of Rouquayrol and Denayrouze was built in 1872, a French museum has in its collection a production model manufactured shortly afterwards and still in working condition.

Figure 4: First autonomous equipment

Source: Army Diving Course Manual, 2012

In 1866, Benoist Rouquaryol developed an air demand regulator for use in a diving cylinder. SELF – Contained Underwater Breathing Apparatus (SCUBA) was born. This equipment had the problem of the high pressure air supply being greatly reduced.

In 1917 the U.S. Bureau of Construction & Repair First began using the Mark V diving helmet. This equipment was connected to an umbilical cable, which allowed work to be carried out in deep waters. The Mark V became a very efficient and used diving tool for decades, being replaced only in 1980 by the MK 12 helmet.

In 1920, research began for mixtures of helium and oxygen to be used in deep dives. In 1924 the U.S. Navy performed the first experimental dives using Heliox.

In 1925 the French officer, Commander Le Prieur developed an autonomous apparatus that used atmospheric air in contrast to that of Fleuss and Davis that used pure oxygen. Air breathing allowed divers to reach greater depths and stay there longer without the risks of oxygen poisoning.

Le Prieur's apparatus consisted of a high-pressure cylinder containing compressed air inside, attached to the diver's body. It had a manual airflow control valve that was connected to a face mask through a hose. As you descended, it was necessary to open this valve wider. This device was widely spread, being used even in the pools of the great clubs of Paris by the nobles and the bourgeoisie as a means of entertainment.

Figure 5: La Prieur apparatus

Source: MAMEDE, 2013

With the advent of this device, man took the first step to abandon the heavy diving suits and free himself from the “umbilical cord” that connected him to the surface, allowing greater freedom of action and swimming in any direction, in contrast to the heavy diving suits in which man was almost anchored to the bottom.

Le Prieur’s device had a serious problem: the air pressure reduction valve was a continuous flow, causing the air to go straight to the middle without being breathed, thus wasting considerable air contained in the device, resulting in less autonomy.

In 1938, Edgar End and Max Nohl performed the first saturation dive. This dive lasted twenty-seven hours at a pressure equivalent to 101 meters deep, and was conducted in the hyperbaric chamber of Milwauke Hospital, USA. His decompression lasted five hours and Nohl was stricken with decompression sickness.

In 1943, Captain J.Y. Cousteau and compressed gas specialist Emile Gagnan, who at the time was studying gas valves for vehicles, developed and perfected the first diving regulator, thus providing better performance to the diving cylinders.

Currently there are several types and models of equipment, all based on the Le Prieur cylinder and the Cousteau-Gaggan pressure regulator.

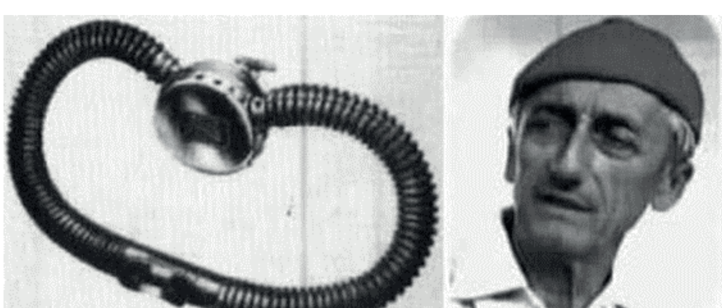

Figure 6: Cousteau-Gagnan pressure regulator

Source: Army Diving Course Manual, 2012

In Brazil, the beginning of diving probably took place during the construction of the Pharus wharf (Praça XV - RJ) at the time of the Empire, continuing the construction of the Gamboa and São Cristovão wharves by French firms, the pier of Praça Mauá (1945), the Ore Wharf (1949) and the old Coal Wharf (1960) by American firms (Christiane Nielsen and others), where they still wore the “Hoof Diving Bells” (Siebe - closed suit).

However, in 1958 the first totally national firm focused exclusively on underwater activities emerged: EBOS - Brazilian Company of Underwater Operations, acting as a pioneer in the demolition of the stones of Aracaju in the Carvoeiro Henrique Laje port in Ibituba, Santa Catarina.

Amateur diving activities began in the forties, when some pilots of the former PANAIR (commanders Edú and Lefévre), brought diving equipment from abroad, contributing, above all, to the development of spearfishing. This activity had a great boost in the fifties with the creation of several clubs, teams and the foundation of the Brazilian Association of Spearfishing (ABCS), which promoted in 1959 the international championship of spearfishing in Angra dos Reis (RJ).

In the early 80s, professional diving got a great boost thanks to Petrobras, with its oil prospecting in the Campos basin and on the coast of Espírito Santo, even performing the deepest dives ever made for the execution of underwater work with divers (350 meters).

Also in the 80’s, with resources from Petrobras, the largest hyperbaric center in Latin America was created, located at the Almirante Castro e Silva Naval Base, on Mocanguê Island, RJ, (Ministry of the Navy) with the objective of research in the area of diving.

Currently, in first world countries, despite investing heavily in research in the area of medicine and physiology of diving, there is a tendency not to expose man to greater and greater depths due to the high risk of operations, in addition to generating serious labor problems. This certainly explains the fact of the growing development of research in the field of the creation of robots and submersibles, including in Brazil.

In Brazil, diving activities were initially developed, more specifically in the Navy, mainly around the activities of repairs to vessels and deactivation of explosive devices, when personnel specialized in torpedoes and mines received specific diving instructions. Important services were performed by military divers, and that military force, for a long time, was the only entity capable of carrying out work in the sector.

Nowadays, the activity of diving is increasingly specialized in the military environment, with several branches of diving, such as scuba diving, deep diving, combat diving, rescue diving, etc.

In the civilian environment, oil prospecting and scientific activities gave rise to a real technological race. This race, which is worldwide, has led man to progress that, until very recently, was impossible to imagine.

3.2 Development of the scuba rescue diving aid device in murky waters

The hydrographic network of Rondônia is represented by the Madeira River and its tributaries, which form eight significant basins: Guaporé Basin, Mamoré Basin, Abunã Basin, Mutum-Paraná Basin, Jacy-Paraná Basin, Jamari Basin, Ji-Paraná Basin and Aripuanã Basin. The Madeira River, the main tributary of the Amazon River, is 1,700 km long in Brazilian territory and has an average flow of 23,000 m³ per second. It is formed by the Guaporé, Mamoré and Beni rivers, originating from the Andean plateaus, and has two distinct stretches in its course, called Upper and Lower Madeira.

The Madeira River has one of the highest sediment loads in the world, with about half of the total sediment in the Amazon River being contributed by this tributary (Meade, 1994; Filizola & Guyot, 2009). At the Jirau dam site, the Madeira River transports 2.1 million tons of sediment per day (PCE, 2004 e 2005).

Figure 7: Madeira River

Source: from the survey, 2018/2022

Next we have figure 8, which presents the composition of the Amazon basin with its tributaries.

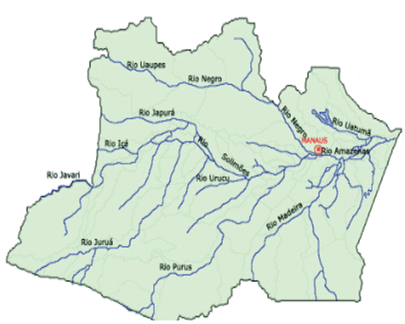

Figure 08: Amazon Basin

Source: http://sosriosdobrasil.blogspot.com/2008/11/ibama, 2018

In recent years, Rondônia has stood out in the Brazilian tourist scene, attracting visitors from different regions of the country. The lush natural beauty of the Amazon region, combined with the growing popularity of sport fishing, has been a major draw for tourists. Previously dominated by men, sport fishing in Rondônia now conquers entire families, who enjoy moments of leisure and excitement in the waters of the local rivers. This transformation reinforces Rondônia's position as one of the main destinations for sport fishing in Brazil.

> "In recent years, tourism has given prominence to the state and attracted visitors from all parts of Brazil to Rondônia. In addition to the natural beauties characteristic of the Amazon region, sport fishing has been the main attraction for these tourists". But if before it was only men who risked themselves in the waters of the Rondônia rivers, today entire families enjoy moments of leisure and excitement and the main reference of fishing in Rondônia" PERIN, Giliane, Ariquemes news available at: < http://www.ariquemesnoticias.com.br/noticia/2014/06/23/turismo-em-rondonia-cresce-com-a-pesca- esportiva.html> accessed on: July 24, 2024)

The population uses this hydrographic potential of the State of Rondônia in the form of entertainment, both for sport fishing and for their leisure, there is a large number of people who frequent these places, which in themselves have a high risk of accidents, which has been proven by the drowning rates in the State.

With the implementation of major infrastructure works in the municipality of Porto Velho, such as the construction of the Madeira River hydroelectric power plant complex, in recent years there has been a demographic surge in the capital. This demographic growth has also contributed to the increase in fatalities, such as drowning accidents.

The depth gauge is an instrument for measuring the depth at which the diver is submerged, and can be measured in meters (metric system) or feet (imperial system).

The monometer will measure the instantaneous pressure inside the cylinders, which will be converted to the amount of gas available to divers, "A diver without a pressure gauge is the same as driving a car on a deserted road without a fuel gauge" (Corazza, Permanent Editions, 2014). Modern pressure gauges are very clear in scale and have good visibility in low light conditions.

These two pieces of equipment described above are extremely important to develop the diving activity, since it is necessary to know the pressure reading of the diving cylinder because this is what will inform how much gas is left for the diver to breathe and the exact depth of the diver because he has a depth limit to perform scuba diving that is directly proportional to the amount of gas used in diving.

Figure 09: Diving depth gauge and manometer

Source: https://www.lojamundosub.com.br/profundimetros/203-manometro-e-profundimetro-mergulho-seasub- bar.html, 2018

Currently, CBMRO has approximately 114 (one hundred and fourteen) Autonomous Rescue Divers in its military staff, for the entire State of Rondônia. Currently, CBMRO has 15 (fifteen) Operational units, two of which are in the capital and the remaining 13 (thirteen) are available, one in each municipality of the State of Rondônia.

The CBMRO scuba diver course, called CMAUT, aims to train military autonomous rescue divers, with technical training to work in rescues and rescue in freshwater locations up to 30 (meters) deep, in murky waters with little or no visibility, which is a characteristic of the rivers of the Amazon basin, where more than 80% of the rivers in our region are of waters with little or no visibility, requiring the use of appropriate equipment. The table below presents the average cost of the equipment needed to perform a dive.

Equipment	**Average value (R$)**
Fin	200,00
Mask	50,00
Snorkel	20,00
Neopreme clothing	500,00
Waistcoat	1.500,00
1st and 2nd Stage	2.000,00
Depth Gauge	700,00
Hoses	500,00
Cylinders	1.500,00
Dive knife	100,00
Neopreme glove	70,00
Neopreme sock	70,00
Lantern	350,00
Total	**7.560,00**

Table 1: Cost of Diving Equipment

Source: from the survey, 2018/2022

The Madeira River is considered to be difficult to dive, it was classified by the renowned French diver Jacques Cousteau, and it is impractical to dive in its waters.

The CBMRO to form a course for scuba divers requires: 45 (forty-five) days of training, provide more than 20 (twenty) instructors distributed in 20 (twenty) curricular components (disciplines) adding up to a workload: 365 hours of class.

Scuba diving equipment is developed so that the diver has visibility in his diving environment, constantly monitoring his guidance instruments and analyzing diving parameters such as depth, residual pressure in the cylinder and reserve regulator.

The diving developed in our region, due to the characteristics of the rivers of the Amazon basin, does not allow divers to visualize any instrument or equipment, thus making it almost unfeasible to practice diving in the region, because the diver will have no way of knowing his depth limit or how much compressed air is left in his cylinder, this being its main safety instrument because without it the diver goes into apnea (absence of ventilation in their lungs), having only the limit of residual air in their lungs to reach the surface until they exchange air with the atmosphere.

When there is an incident or accident involving people in the aquatic environment, such as drownings in rivers in our region, rescue divers are immediately called to locate and rescue the victim's body, regardless of the characteristics of the river waters. With this, making it a function of unique characteristics, since the same with little or no safety in his dive, will perform it in favor of his function, as there is no price that pays the delivery of a loved one to his family so that they can perform their last tributes and farewell.

However, after analyzing this problem, it was noted the need to create an electronic device: Autonomous Rescue Diving Aid Sensor in Turbid Waters in the Western Amazon, which will assist in the orientation and reading of parameters in dives developed in the Amazon region. The device will work as follows: Before the diver develops his activities, he will place it attached to his arm, through a neoprene strap which goes inside a device, working as follows.

At each meter in aquatic submersion, it will read the depth and when it reaches the pre-established depth limit, the device will emit a vibration signal on the diver's arm, which will know at what depth it will be through this signal that will be pre-established with the diver, for example: The diver will perform a dive and defines that his limit in that dive will be 20 (twenty) meters, so the diver will want the device to signal when it reaches 20 (twenty) meters. Thus making a safer dive.

3.3 Materials

The following materials were used in the construction of the prototype and in the performance of the tests.

- 01 (one) LM35 temperature sensor;

Figure 11: LM35 temperature sensor

Source: https://www.google.com.br/search?q=sensor+de+temperatura1NHXL_pt, 2018

- 01 (one) HPT604 pressure sensor;

Figure 12: HPT604 Pressure Sensor

Source: https://portuguese.alibaba.com/product-detail/Holykell-OEM-HPT604-Hot-Electronic-Analog-60306012459.html, 2018

- 01 (one) vibration sensor;

Figure 13: Vibration Sensor (Shaft Offset Motor)

Source: https://www.google.com.br/search?q=sensor+de+temperatura+LML_pt, 2018

- 01 (one) buzzer;

Figure 14: Buzzer

Source: https://www.google.com.br/search?q=buzzer+imagens, 2018

- 01 (one) 10k potentiometer;

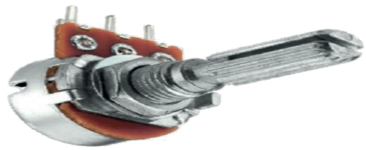

Figure 15: 10k Potentiometer

Source: https://www.google.com.br/search?q=potenciX&ved=0ahUK, 2018

- 01 (one) 16x2 LCD;

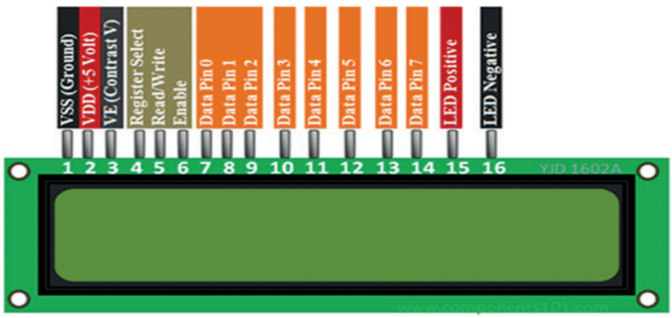

Figure 16: 16x2 LCD

Source: https://www.google.com.br/search?q=LCD+16x2&rlz=1C1NHXL_pt

- 01 (one) ATMega328;

Figure 17: ATMega238

Source: https://www.google.com.br/search?q=ATMega328&rlz=1C1NHXL_pt, 2018

- 01 (one) printed circuit board (PCI)

Figure 18: Printed Circuit Board (PCB)

Source: https://www.google.com.br/search?q=placa+de+circuito+impresso+(PCI)XL_pt, 2018

The equipment was acquired and assembled on a protoboard board on a bench in the university's electricity laboratory. figure 19 shows the assembly and testing.

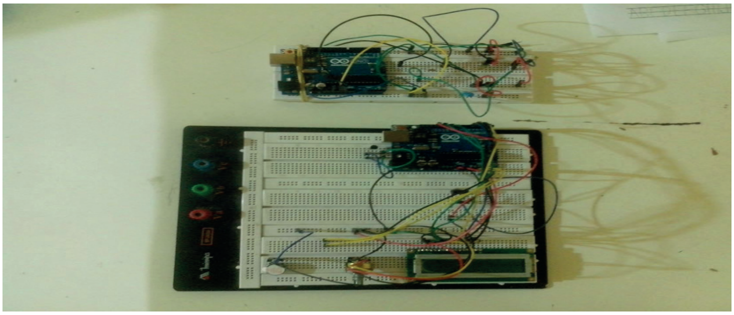

Figure 19: Prototype mounted on the protoboard

Source: from the survey, 2018/2022

A logic circuit was created to integrate the components and create the functionalities, shown in figure 20.

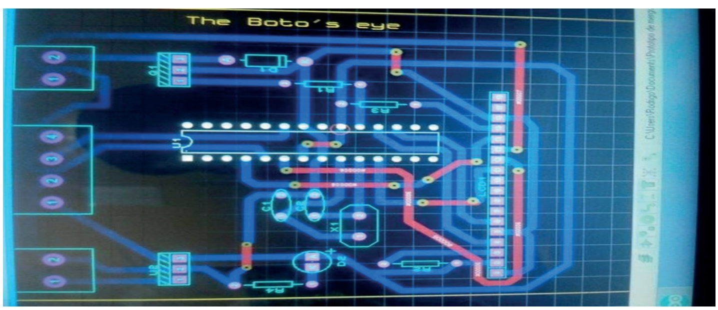

Figure 20: Prototype circuit

Source: from the survey, 2018/2022

Bench tests were performed and the simulation parameters were obtained, as well as the prototype was mounted on the printed board, as shown in figure 21.

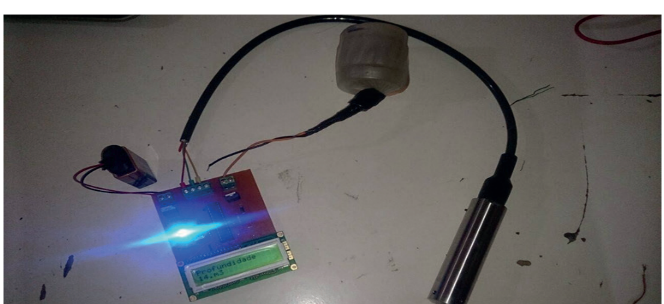

Figure 21: Device mounted on the printed board

Source: from the survey, 2018/2022

After the bench tests, the field tests were carried out, figures 22 and 23 demonstrate the prototype in the field.

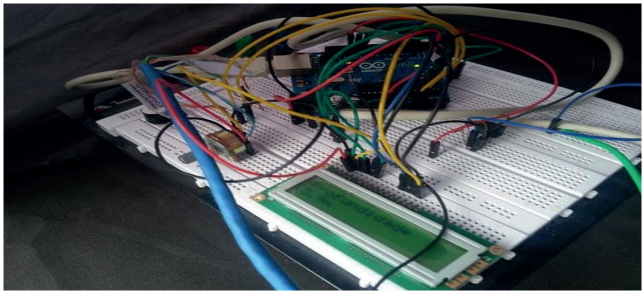

Figure 22: Prototype in field test

Source: from the survey, 2018/2022

Figure 23: Test dive of the prototype in the Candeias River

Source: from the survey, 2018/2022

4 I CONCLUSION

It was verified that the sensor suffers a variation directly proportional to the voltage, it was programmed to emit a vibrating signal at a programmed pressure variation (0.08V = m), having a variation limit of 4.5V that corresponds to 50m (meters) within the expected limit that would be 30m, limit for rescue scuba diving in the CBMRO.

The programming of the device was implemented with the following parameters: intermittent vibrating signal for pre-established voltage with a limit of 2.4V that corresponds to 30m depth limit that a scuba diver can reach, so the diver will not run the risk of exceeding his diving limit or running out of gas in his cylinders, its effectiveness in use as an Autonomous Rescue Diving Aid Sensor in Murky Waters in the Western Amazon is evident.

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