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Smart mineral water bottle using internet of things

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Abstract

The objective of this work is to develop an IoT bottle of mineral water. The system will periodically check your water level, when it is empty, it will automatically fill it from another common carboy that is at ground level, thus avoiding the repetitive effort of changing carboys. This system was implemented to serve the elderly, people with special needs and the general public, through a low-cost microcontroller, NodeMCU ESP8266, using a horizontal float-type water level sensor, a mini diaphragm water pump and a relay. In addition, the platform allows the monitoring and control of metrics through an MQTT application for Android.

Keywords: water bottle; system; iot; microcontroller; mqtt; app;

1. Introduction

Technology, over time, has been helping the human being in the execution of several activities. Its development has provided benefits and improvements in several areas. With operations, from automation of industrial works, to the creation of domestic devices. Today's modern world is seen as inoperative without its presence, whether for the execution of complex algorithms or a simple daily activity. For example, technology is present even in a simple remote control TV channel change. At some point in the past, imagining a remote control in a home environment, perhaps, could have been interpreted as unnecessary or exaggerated. But today this is seen as essential, both to turn on an air conditioner and to open the garage door. Over the years, people have become accustomed to using inventions that facilitate, or even automate, many of these simple tasks. Thus, the need for innovation is well nested with day-to-day needs, and with that, more and more equipment appears willing to perform some of these simple services.

The residential environment, full of tasks, is usually under the eyes of developers, who spread their knowledge over the internet. Currently, there is a lot of work, both scientific and in open source online communities, developing IoT (Internet of Things) devices to automate many of these tasks. No matter how simple a task, there will always be a person with limitations to perform it. Even a simple change of a 20 liter mineral water bottle can be a problem as it takes considerable effort to lift that weight. This task can result in minor domestic accidents, or be an aggravating factor for potential health problems, such as a spinal problem. In addition, this difficulty in changing the bottle is real in the case of people who live alone and have some physical disability or simply because they are elderly. To combat this problem, this work was conceived and implemented. For this, the concept of IoT was used, creating a platform that aims to alleviate this limitation, solving the problem with automatic filling of the IoT bottle, thus eliminating the need to change it.

1.1 Theoretical foundation

The [Chaudhary et al. 2019] presents the idea of IoT as interconnections of analog and digital devices, homogeneous and heterogeneous, that can communicate efficiently. It also highlights the importance of IoT in building solutions in various areas, such as home automation, in a national campaign for PwD (Person with Disabilities) in India, and even in devices that help in agriculture or in the prediction of natural disasters. The importance of cloud computing and 5G internet network in the growth of these types of devices was also reported. In addition, the growth in the supply of embedded devices with greater computing power, robustness and compactness offer good characteristics to provide better projects, making them ideal for dedicated applications.

Next, some IoT works that served as a basis for the construction of the proposed system were analyzed. Each of these works, even having different applications, contributed in some way to this development, even with a simple example of functionality. It was observed that the work [Tantitharanukul et al. 2017] MQTT-Topics Management System for Sharing of Open Data proposes an MQTT topic management standard based on his previous work, which was on naming standards for topics. Although this question represents a significant discussion, its real contribution to this development lies in the explanation of the MQTT architecture. The work [Shakthidhar et al. 2019] Arduino and NodeMCU based on Ingenious Home Objects Monitoring and Control Environment develops an IoT system connected to the internet through NodeMCU and commanded by Arduino in order to control more home devices through a relay module. For this, an Arduino UNO and the NodeMCU ESP8266-12E, an 8-channel relay module, were used. In addition to executing voice commands with the Virtual Assistant and storing data in Firebase, both from Google. According to the author, this model reduces costs and promotes greater compatibility between IoT devices in the residential environment. Their collaboration is present in the integration of NodeMCU and the relay module for load activation. The work [Wongmeekaew et al. 2019] Wireless Sensor Network for Water Quality Monitoring for Tilapia Pond proposes an IoT system capable of identifying water quality by monitoring its level and factors such as pH, amount of oxygen and temperature. For this, a NodeMCU ESP8266-12E microcontroller and Raspberry Pi were used, as well as an oxygen sensor, a temperature sensor, a pH sensor and a capacitive water level sensor. All this to monitor the conditions of the tilapia rearing environment. Although the functional nature of the capacitive level sensor used is different from the sensor of the proposed system, its operability is equivalent to that of any other type, thus serving as a parameter. The work [Kodali and Sarjerao 2017] A Low Cost Smart Irrigation System Using MQTT Protocol presents an IoT system for smart irrigation capable of monitoring soil moisture through sensors and connecting a water pump through a relay triggered via website or application. All this commanded via MQTT (Message Queuing Telemetry Transport) protocol. For this, a NodeMCU ESP8266-12E microcontroller, a soil moisture sensor, a DHT22 air temperature and humidity sensor, a relay module and a water pump were used. Thus solving a simple local problem that was to avoid traveling great distances just to turn on a pump. This project deserves to be highlighted, as your collaboration with this work is of great value, as all its characteristics are similar. For example, even if the sensor in question is not for water level detection but for soil moisture, the way the sensor in question collects data from the NodeMCU is still very useful. In addition, he also cooperated with the handling of the MQTT protocol.

Table 1. Articles resource

Articles	Microcontroller	Device	Communication
[Tantitharanukul et al. 2017]	-	-	MQTT
[Shakthidhar et al. 2019]	NodeMCU ESP8266 Arduino UNO	8 channel relay module	MQTT
[Wongmeekaew et al. 2019]	NodeMCU ESP8266 Raspberry Pi	Sensors: water level (IDC), pH, Oxygen and Temperature	MQTT
Kodali and Sarjerao 2017]	NodeMCU ESP8266	soil moisture, DHT22, 1-channel relay module and Water pump	MQTT

It is possible to observe in table 1 the main resources and some functionalities of the analyzed works. By correlating water level detection [Wongmeekaew et al. 2019], with relay activation via NodeMCU from [Shakthidhar et al. 2019], with the activation of the pump and sending the command via the MQTT application by [Kodali and Sarjerao 2017], we will have all the features proposed by this IoT system.

2. Materials

Figure 1 presents a succinct view of the proposed system through the simplified flowchart that expresses its main operations, thus prioritizing the concealment of some details considered secondary. The general operation is as follows: the water level sensor, installed at the base of the IoT carboy, informs you in real time if it is dry or not. After analyzing the state of the bottle, the filling action will be activated, in case of a positive result, otherwise the process will be restarted.

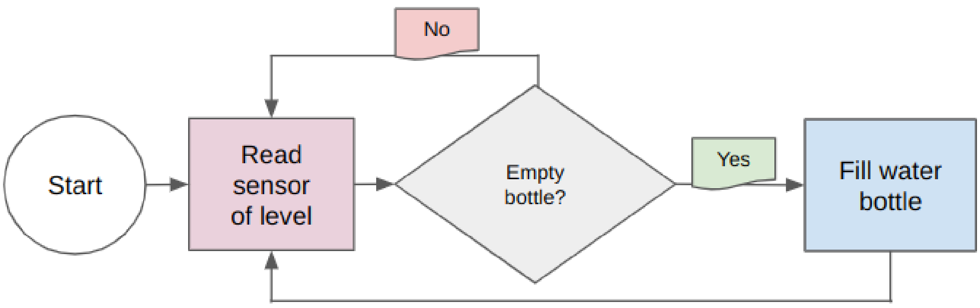

Figure 1. simplified system flowchart

Table 2 contains all the low-cost hardware resources that participate in building the IoT system. Specifies which types of modules are used and their respective values. Below, all the major hardware and software features will be described briefly. Already some secondary resources can be presented in the course of other approaches.

Table 2. Resources used

Materials	Module	Price
[A] NodeMCU	-	R$ 50,00
[B] Level sensor	NodeMCU ESP8266 Arduino UNO	R$ 20,00
[C] 5VDC LDR relay	NodeMCU ESP8266 Raspberry Pi	R$ 20,00
[D] Water pump	NodeMCU ESP8266	R$ 22,00
[E] LED	red	R$ 0,10
[F] USB cable	male-male type-c	R$ 2,00
[G] Resistor	2.2kΩ and 390Ω	R$ 20,00
[H] Battery	5V	R$ 20,00
[I] Protoboard	860 points	R$ 20,00

2.1 Hardware

The microcontroller chosen to manage all the resources of this project is the NodeMCU (Table 2 A). This will be responsible for data processing, triggering the relay device and reading the water level sensor through its programmable pins, in addition to providing internet connectivity, among other resources. According to [Parihar 2019], it is a platform widely used in IoT projects with support for several languages for easy integration with the Arduino IDE (Integrated Development Environment) [Arduino 2021], used for firmware recording via USB (Universal Serial bus). The USB port also serves as a channel for powering the microcontroller, which will supply voltage between 2.5V to 3.6V and 600mA [Espressif 2020] for some other devices. This device is produced by several manufacturers, thus enabling its low cost.

According to [SIBRATEC 2021], the side microbuoy switch (Table 2 B) “was developed for automation of water level control in reservoirs”. It works with voltage up to 220VAC (Voltage Alternating Current) and 0.5A, and also has an IP65 protection degree, that is, it is protected against water jets [FIBRACEM 2021], providing safety when submerging in water. The switch also has two operating settings: NO (Normally Open) and NC (Normally Closed) (Figure 2).

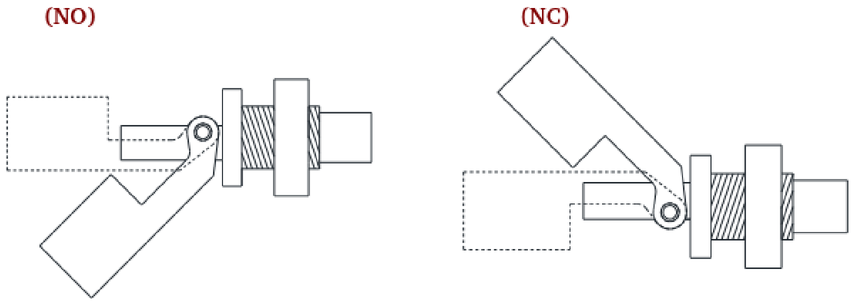

Figure 2. water level sensor [SIBRATEC 2021]

Generally, a relay is seen as an electromechanical switch responsible for safely activating loads. The relay module (Figure 3 blue area) of table 2 C has three input pins for triggering circuit (Figure 3 green area): the VCC (Voltage Current Continuous) pin, which operates at up to 5VDC (Voltage Direct Current) and current 15 -20mA; the GND pin (Graduated Neutral Density filter), which operates at 0VDC; and the IN pin, responsible for the relay tripping signal. This needs a low voltage digital signal i.e. any voltage lower than the VCC pin. The relay itself (Figure 3 yellow area) has three output pins: the COM (common) pin, the NO pin and the NC pin, which allow connections to the load circuit. In addition to the above values, the values referring to the 30VDC and 10A or 250VAC and 10A operating mode are also printed on the module. This also has diode protection against the relay coil electromotive force and isolation between the drive circuits and the load circuit.

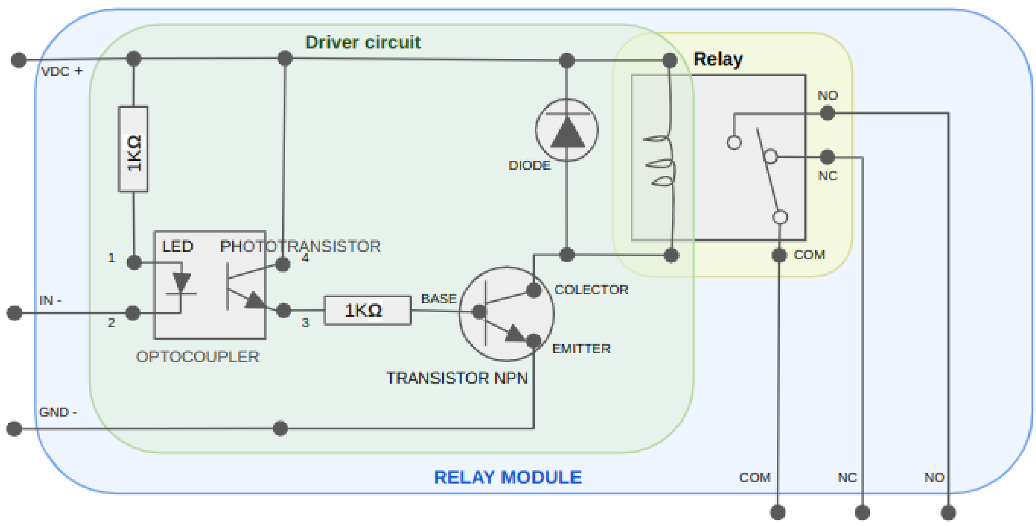

Figure 3. relay module circuit

The diaphragm water pump (Table 2 D) produced by [Tecnologia 2021], works with voltage between 4V-6V, has a flow rate of 1.2 - 1.4L/min with a water outlet elevation of up to 3m in height , according to its manufacturer.

2.2 Software

The MQTT protocol, according to [Tantitharanukul et al. 2017], was created in 1999. Its main benefit lies in sending lightweight and low-bandwidth messages, which has contributed to its wide adoption in IoT projects. The MQTT architecture is known as Publisher/Subscriber, which can be boiled down to customers and an administrator. The latter, the central controller, is called the MQTT Broker (Figure 4), which, receiving a message from an MQTT topic, coming from a publishing client (Figure 4), correctly filters and distributes it to the subscribing clients (Figure 4) this same topic [Hivemq 2015]. The integration of MQTT with NodeMCU can be done through the library for ESP8266 which is available through the link [O'Leary 2020].

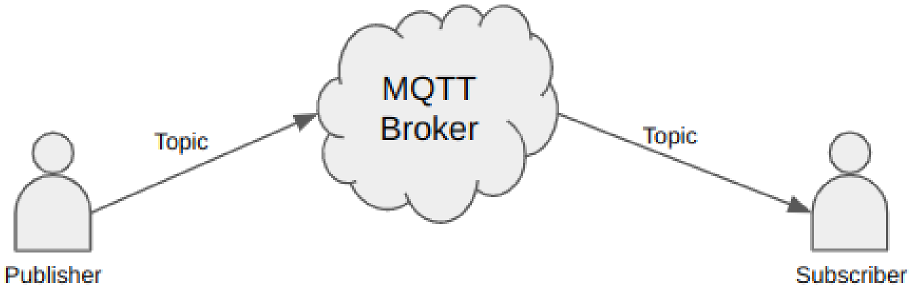

Figure 4. mqtt architecture

The APP IoTMQTTPanel application [Kundu 2021] offers important features for the project, such as: sending messages/commands, useful in the testing phase; and displaying data in different types of components, including a graph, received from the MQTT server side. It has an interface that allows modeling an application according to the needs of each project, thus allowing the creation of operability on the MQTT client side.

3. Methods and Operation

Regarding the problem, the method that aims to combat it is in the detection of empty bottle and in the automated pumping of water. Figure 5 illustrates the general operability of the system through the flowchart. When turning on the NodeMCU, the algorithm will run (Figure 5 Home). It will then go through the configuration step and attempt to establish connections (Figure 5 A). Then the system will enter the operating mode collecting the value read by the level sensor (Figure 5 B). Going through the verification of the bottle level, triggering the action of filling it, if its state is of an empty bottle (Figure 5 C). Ending the cycle by sending the data to the IoTMQTTPanel APP (Figure 5 D).

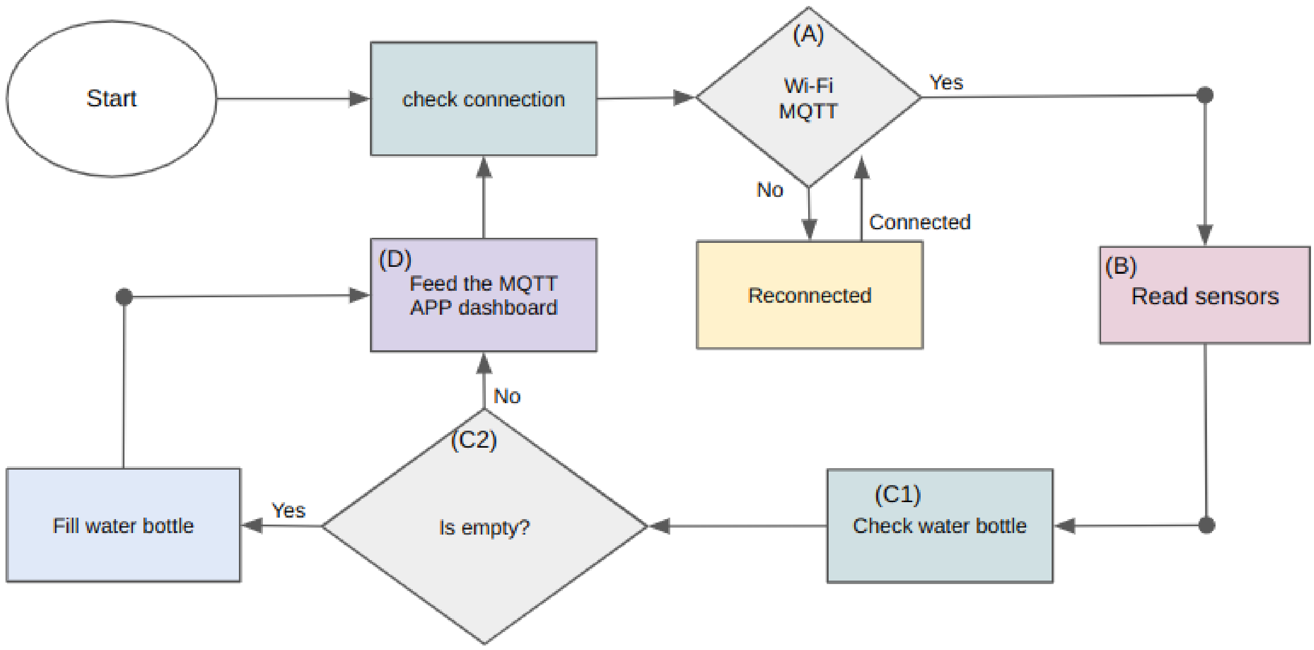

Figure 5. general system flowchart

Figure 6 provides the entire circuit diagram of the IoT system. The level sensor (Figure 6) is connected to pins 3.3V and D8, which is configured as INPUT. The sensor will activate when the water bottle is below the allowable level. In this absence of water, it can operate in two ways: the NO configuration (Figure 2) will be interpreted as a 0 signal by the microcontroller; NC (Figure 2) will mean a 1 signal. This last setting was chosen as most of the time the bottle will contain water, which will mean having the circuit open, which will result in energy savings.

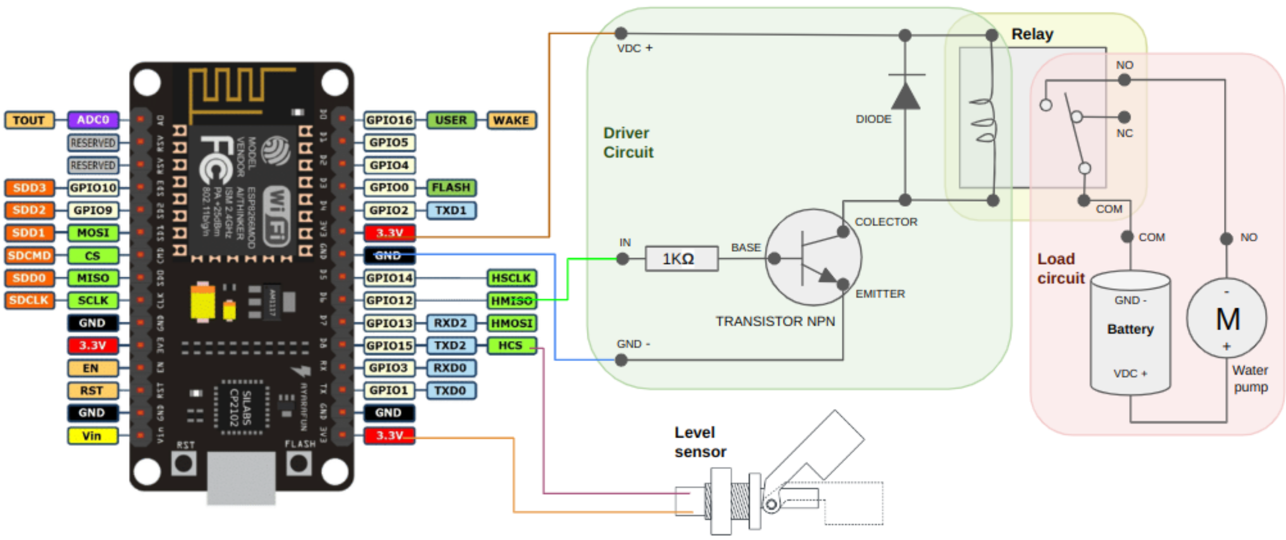

Figure 6. system schema

The relay module (Figure 6 blue area) is connected to pins 3.3V, GND and D6. The D6 pin, when sending a negative digital signal to the IN pin, will activate the opto-coupler (Figure 3), that is, its internal LED will light up, inducing the activation of the phototransistor. In this way, upon receiving the positive signal at the base of the NPN transistor, its terminals (Figure 6 COLLECTOR and EMITTER) will switch, thus feeding the relay coil, which in turn will change the NO and NC states (Figure 6), which finally will result in the load being triggered (Figure 6 Pump). The water pump power circuit (Figure 6 red area) supplies 5 VDC from a secondary source (Figure 6 Battery). It is completely independent of the drive circuit (Figure 6 green area), providing protection to the microcontroller.

4. Results

The assembly of the final prototype of the system can be seen in Figure 7 A. Then, tests, validations, adjustments were carried out to eliminate possible errors until reaching the MVP (Minimum Viable Product) stage, which is observable in Figure 7 B. All relay trip tests, either by triggering via level detection with the sensor, or by pressing the button, were positive. The big obstacle in this project was mainly in the validation of the water pump type. With the correctness of the diaphragm pump (Figure 7 C), a perfect pumping of water with the necessary elevation was then provided, thus enabling the main functionality of the project. All water suction tests with a height of 1.80 m became positive from this correction. A video was also recorded [d. O. Junior 2022] with a record of one of these tests, executing the completes the functionality of the project.

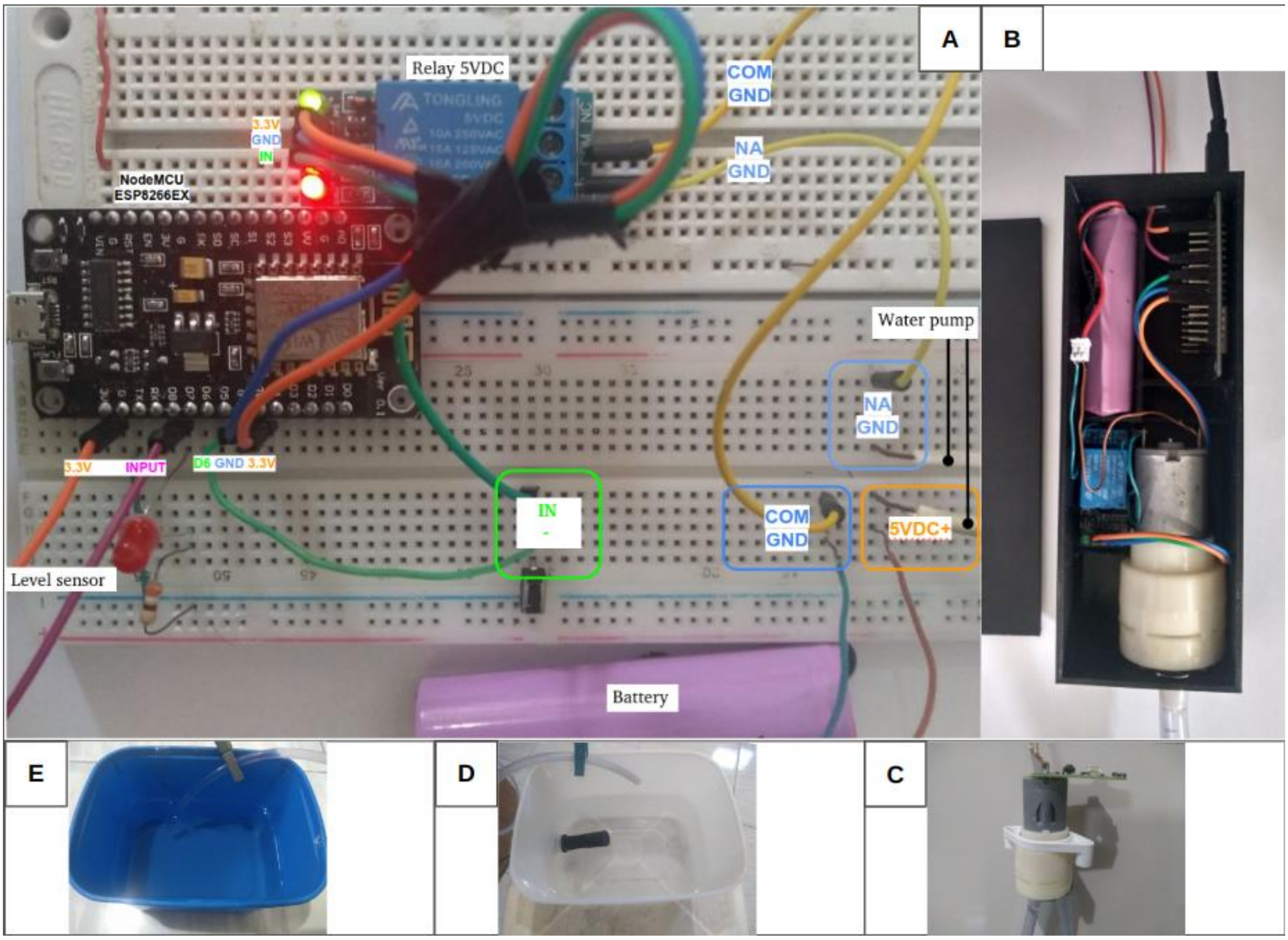

Figure 7. system prototype

Table 3 shows the results of the pump suction time tests in liters per second (L/s) at a height of 1.80 m. For this, two 2L containers were used. The white container contains the level sensor (Figure 7D) and represents the IoT carboy. The blue one, filled with exactly 1L of water (Figure 7 E), represents the common carboy at ground level. The average obtained with the tests in table 3 was 1L/50.7s. So, to fill an IoT bottle, it will be 20L/1014s or 20L/16.9min. An acceptable amount of time to complete a non-vital task.

Table 3. Water pump suction time (L/s)

Test	1	2	3	4	5	6	7	8	9	10
meter (m)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
liter (l)	1	1	1	1	1	1	1	1	1	1
second (s)	52	50	51	49	49	50	53	51	50	52

Figure 8 shows the MQTT application, responsible for displaying real-time metrics data and sending commands. The application plays the role of Subscriber client as well as Publisher client on MQTT topics. In the first function, it is possible to display the data and alerts in the application as it is subscribed to MQTT topics fed by the Publisher client, NodeMCU. Having this functionality performed by the application, it is possible to obtain a more comprehensive view of the data in several components simultaneously, that is, without concurrency. Thus, it was possible to reduce costs with LCD display and I2C adapter module. In the second, it is possible to perform the IoT remote control function, sending commands to MQTT topics, making it possible to arbitrarily trigger and/or interrupt IoT carboy filling events.

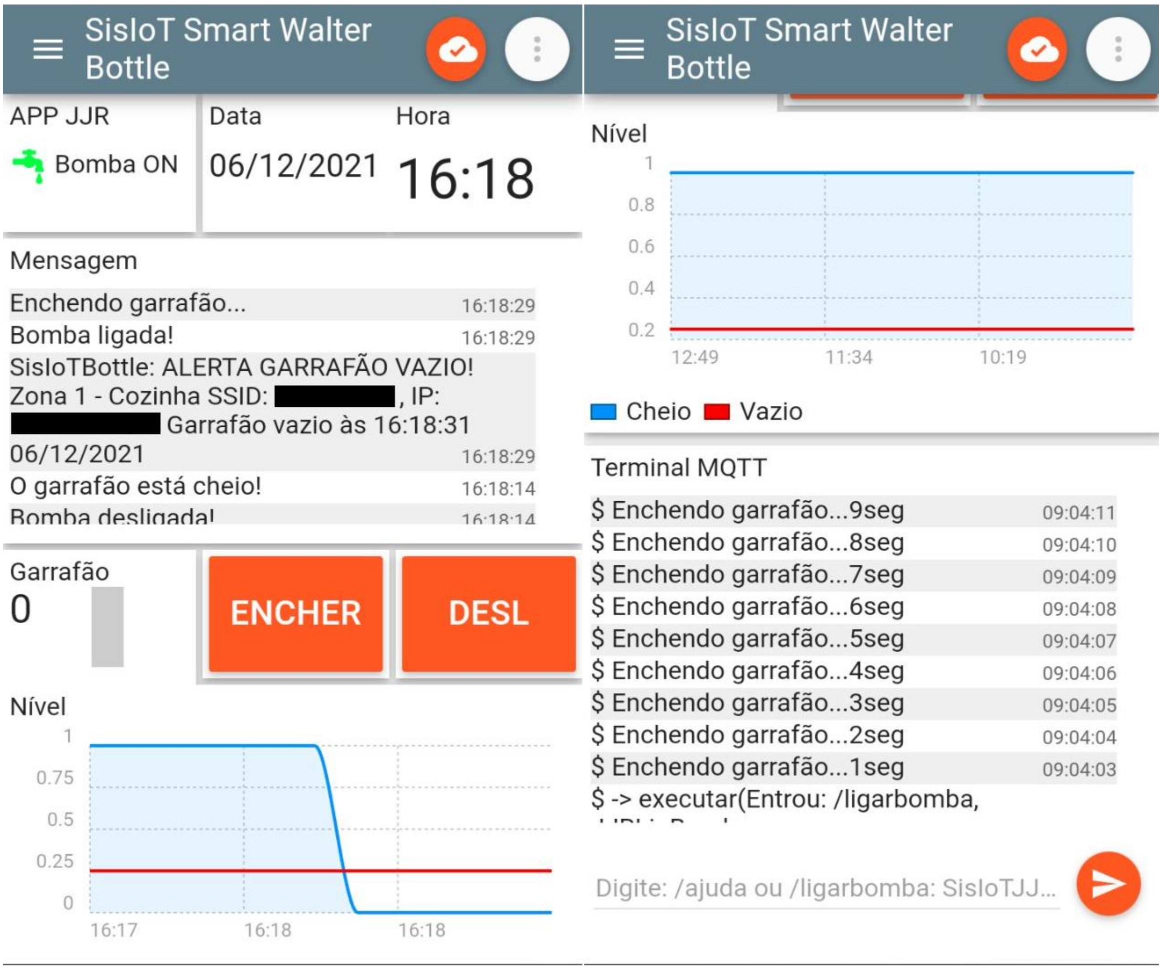

Figure 8. app iotmqttpanel [Kundu 2021]

5. Discussion

As for the water pump, the validation performed at a height of 1.80 m, as shown in table 3, also indirectly implied the other lower heights. Initially, attempts were made with the RS-360h mini water pump for irrigation [Autocore, 2021], which required the continuous insertion of water at its inlet. The 12V water pump for the car windshield washer reservoir was also tested. Both results were unsatisfactory regarding the elevation of the water output. Finally, the expected adjustment occurred with the validation of the diaphragm pump.

Regarding the application, it is worth mentioning that, although it adds great value to the project, it has some disadvantages. It works with a block approach, similar to the MIT APP Inventor [Google, 2010], which results in laborious manual construction of each instance. Also, it lacks a message alert feature in the smartphone's status bar, thus culminating in the process of opening the application to know what the state of the IoT bottle is.

6. Final considerations

In this project, an intelligent system was developed capable of automatically carrying out the task of filling a bottle of mineral water. The functionalities resulting from this prototype are in fact usual and collaborative to solve the exposed problems, that is, an IoT system was built capable of detecting the low water level and automating the filling. In addition, this project demonstrates great commercial power with an approach to the elderly and PwD, in addition to the common public.

For future work, there are four steps to be taken in order to evolve the prototype into a product: the first would be the inclusion of more water level sensors in different positions of the carboy for real-time monitoring; the second challenge would be the inclusion of a battery charger circuit; the third would be the inclusion of an order alert, for example, via Telegram, with the water supplier; and finally, it is clear that this project will tend to improve with the creation of a multiplatform application that has the important functionality of alerts and also the sharing in groups of users.

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