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Low-cost method to measure and remotely monitor water tank level

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Abstract: The rising area of Internet of Things (IoT) intends to unify sensors data all over the world through the web. In this context, new technologies emerge to bring integration between society and those data. This paper proposes a low-cost method to measure water tank level and send it to the Internet for remote monitoring. A search was made on patents and papers index databases to verify similar technologies. Using a cheap microcontroller and wires as switches, the water level was measured, this data was uploaded on the cloud through MQTT protocol, in JSON format, and even a relay for a water pump was actuated. Further, some other ways to improve this work and how it differs from existent technologies were discussed.

Keywords: Internet-of-Everything; Measurement; NodeMCU; ESP8266

1. Introduction

In the glances of a less wasteful era, sustainable technologies are emerging. New ideas to mitigate water consumption and electricity waste are seen as good ways to introduce incoming innovations to people's house.

Based on that, questions are made about how to make simple, reachable to everyone, and affordable devices. The growing Internet of Things (IoT) technologies come to put everything online (Gubbi *et al*., 2013). For this purpose, many microcontrollers are used to read sensors, drive actuators, send data to servers on the web, and even analyse data on the edge of computation, what is called fog computing (Bonomi *et al*., 2012).

Although many microcontrolled boards like Arduino, NodeMCU and Raspberry Pi become more accessible to almost everyone, there are still complex questions about integration between these microcontrollers, sensors, actuators and the cloud. From these questions come various forums on the Internet, known as DIY (Do-It-Yourself) websites. The DIY community helps ordinary people to design and build their own device and offers an opportunity to deal with homemade technology (Wolf; Mcquitty, 2011).

Thinking on those questions, the objective of this article is to propose a low-cost method for water tank level measurement and its further remote monitoring through IoT technologies.

1.1 State of the art

Patents index and one paper index databases were used to verify similar projects. Key expressions were elaborated and combined with some thesaurus to search on these databases. These expressions can be seen in Table 1.

Two patent index databases were consulted: Derwent Innovations Index (DII) and Espacenet, and one paper index database: Scopus. A few productions found by this search, with similar characteristic with this work, will be commented further.

	AND			
OR	Water level	Switch	Remote Monitoring	Low cost
	Tank Level	Sensor	Remote Control	Low-cost
			MQTT	Low-priced
				Popular
				Cheap

Table 1: Key expressions for searching - AUTHORS

Most projects involving water level measurement, as seen on the works of Asadullah; Ullah (2017) and Pernapati (2018), use ultrasonic sensors to measure water level by emitting and receiving sound waves. There are plenty of cheap ultrasonic sensors on the market, and its integration with microcontrollers like Arduino is easy to find on the web.

The work of Xueliang (2007) uses water surface reflection and a photoresistor to actuate on a relay when the determined water level is reached. The device emits a light beam and a photoresistor receives it after reflected on the water surface. Depending on the water level, the light beam returns brighter or duller. Even if the author's objective is close to that of this work (to change the water level), he uses an analogue variation sensor (photoresistor). Those photoresistors, commonly called LDR (Light Dependent Resistor), are usually easy to find and not expensive to buy on the Internet.

In a DIY website (“Simple Water Level Indicator Alarm Circuit Diagram”, [s.d.]) a very similar project was found, with almost the same object (to build water level switches), however, it uses an electronic circuit with some transistors to act as switches and turn on LEDs (Light Emitting Diodes) to level indication. It just indicates the water level locally without using any microcontroller to manipulate the data.

The invention of Wei *et al.* (2016) uses a pressure sensor wired to a float to measure the pressure on the water column and indirectly point the water level. It is very useful in a large water reservoir, indicating water level in a specific area.

Therefore, a simplified low-cost method to measure certain levels of water was proposed, using the wire itself as the switch, and to monitor this data remotely, using a microcontroller connected to the Internet.

2. Method

ESP8266 is a low-power microcontrolled system-on-a-chip (SoC) with Wi-Fi integrated (Saha; Majumdar, 2017). It was adopted to analyse data from water level switches, to determine the estimated tank level and to send this data to the cloud because of its programming simplicity.

To monitor this data, the microcontroller was programmed to send the level value and the sensors data through JSON (JavaScript Object Notation) (Severance, 2012) format to an MQTT server. MQTT is a popular protocol largely used on IoT applications (Yiming *et al*., 2016). Furthermore, an ESP8266 digital pin was used as an output, to possibly actuate on a water pump if the level is too low or too high.

The JSON format can summarize all data in one single message, passing it through one MQTT topic. It is worth saying that there are plenty of MQTT servers on the web that can be rented, free or for some price, as “CloudMQTT”, “IBM Cloud” and “Microsoft Azure”.

ESP8266 has an open-source firmware and development kit called NodeMCU (Saputra; Lukito, 2017). It has some vital components for ESP8266, like a voltage regulator, and it is easier to use by common users. Then NodeMCU was chosen to interface the switches to the MQTT server.

2.1. Proposed Circuit

To connect NodeMCU to the switches, digital pins were used. Those can be used as inputs or as outputs. Pins D2, D5, D6 and D7 were chosen as the switches input pins, and pin D3 as output for the water pump. The pinout can be changed as user wishes, regarding microcontroller’s manual rules.

The digital input pins must be grounded to set it to zero when no water has reached them, thereby pull-down resistors were attached to grant that zero reference. The resistors values may differ depending on the water conductibility, but they must be of great resistance to ensure water electric conduction will set pins to the High level. For this application, the value of 1MΩ (one Mega Ohm) was great enough.

The pump and relay circuit is a suggestion, but the core of this work is the water level measurement and monitoring.

The schematic of the circuit was made with software Fritzing and it can be seen in Figure 1.

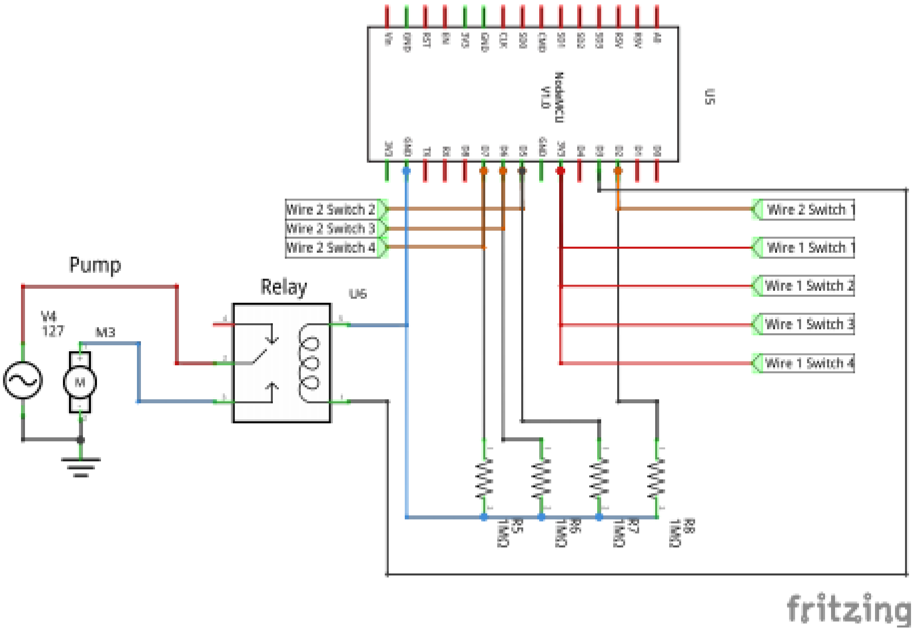

Figure 1 - Schematic of the circuit
Source: Authors

Figure 2 represents switches wiring up to the tank. Each pair of wires should be connected one to the voltage source (3.3 Vcc (Voltage common collector) pin from NodeMCU) and the other to its corresponding microcontroller pin.

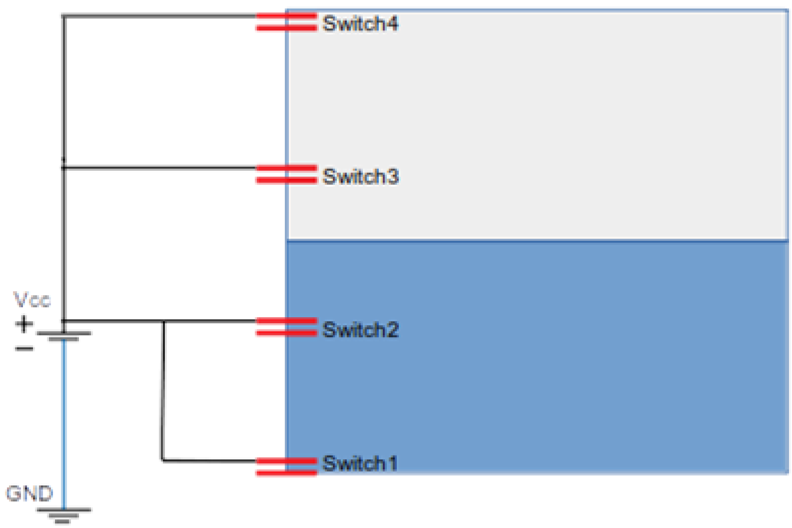

Figure 2 - Switches Representation
Source: Authors

When the water reaches each switch level, it closes the electric contact, taking the input pin to the High level and then some evaluations are made. In the example with four switches, there are six evaluations:

- If all switches are at the Low level, the water level is 0%;
- If only Switch 1 is at the High level, the water level is between 0% and 33%;
- If the switches 1 and 2 are at the High level, the water level is between 33% and 67%;
- If the switches 1, 2 and 3 are at the High level, the water level is between 67% and 100%;
- If all switches are at the High level, the water level is 100%;
- Any other combination of switches represents an error in some switch(es) and they must be checked.

It was noticed that the number of evaluations is always n+2, where n is the number of switches.

For the optional actuator logic another two evaluations are made, taking account the same 4-switches case:

- If the current water level value is below the past value and the current value is less or equal to 33%, the actuator pin is set to the High level;
- If the current water level value is above the past value and the current value is equal to 100%, the actuator pin is set to the Low level.

With those logics, the microcontroller sends the level data to a preconfigured MQTT server, what can be viewed on smartphones by diverse apps, for example, “MQTT Dash”, for Android devices or “MQTTool”, for Iphones and Ipads.

To show timestamp on MQTT message, an NTP (Network Time Protocol) server was used. Depending on the region of the world where the device is placed, a close NTP server must be configured with the correct time zone (Mills, 1991).

The method flowchart can be seen in Figure 3. Condition 1 and Condition 2 represents respectively the actuator logic mentioned above.

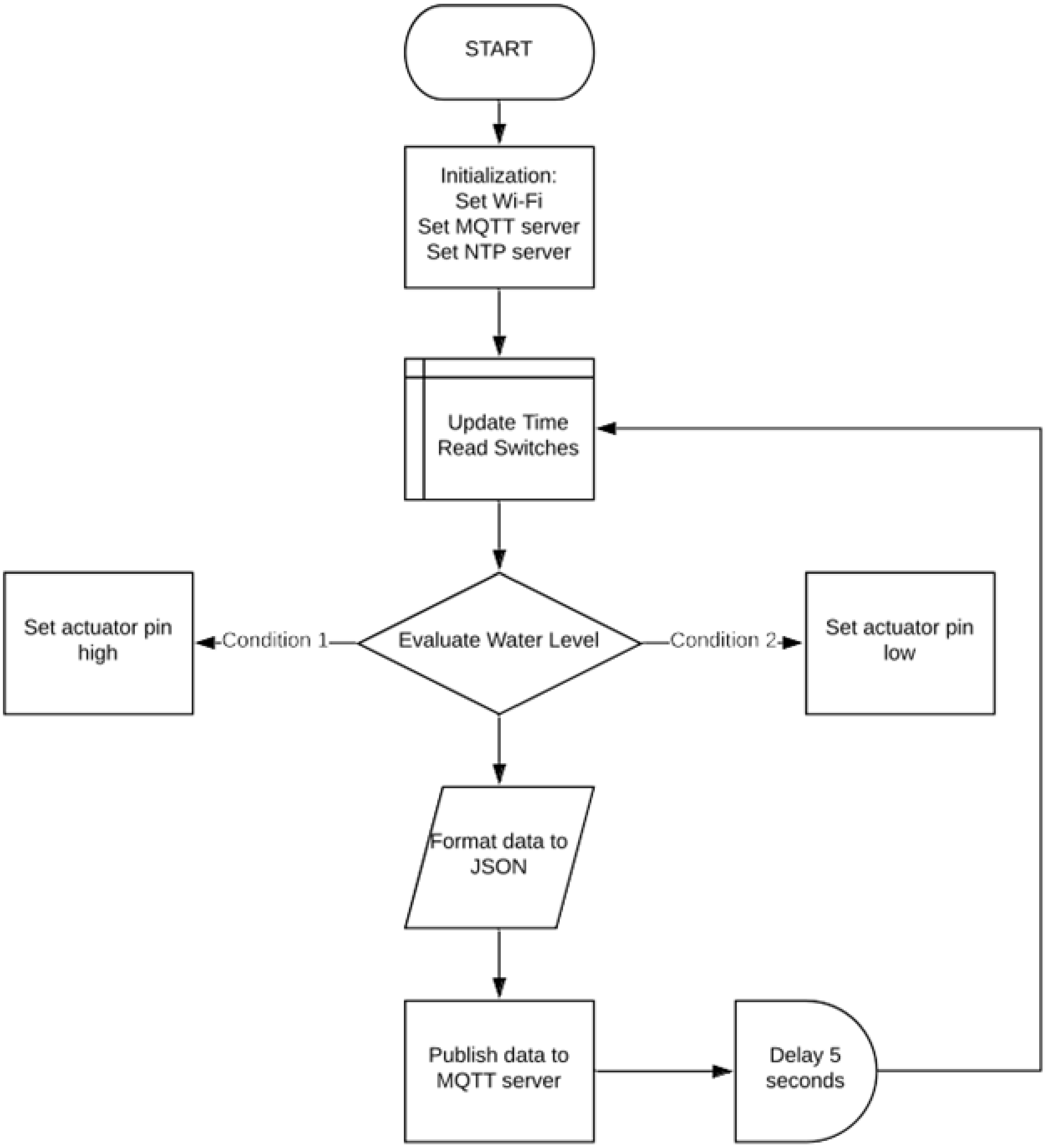

Figure 3 – Logic flowchart
Source: Authors

3. Tests and Results

Experimentation was used to verify the conductibility of freshwater. A measurement on the water at hand was made and it was verified it conducted approximately 2 µA (two microamperes) of electric current under a voltage of 3.2 V (three point two volts) in a 1.5 mm (one point five millimetres) wire. Even though its resistance could be calculated based on

Ohm's law (Personnel, 1970), it was influenced by the microcontroller port impedance and other electromagnetic interferences, what was confirmed with an ohmmeter test, indicating a floating resistance around 70 kΩ (seventy kilo Ohms). These tests reveal how difficult is to measure water resistance or conductibility. The work of Kolz (1993) discusses more in-water electrical measurements.

Tests were made with 1.5 mm (one point five millimetres) wires and the distance between wires at each switch were approximately 2 cm (two centimetres). However thicker wires and nearer distances should work as well.

For the tests, a local MQTT server was used and the JSON message format contained: timestamp, Switch 1 state (High or Low), Switch 2 state, Switch 3 state, Switch 4 state and the water level in percentage. The resulting string was:

{"time":"12:38:45","data":[true,true,true,false],"level":"67%~100%"}

To diminish energy cost, the microcontroller loop delay was defined to five seconds, but it could be larger to increase the time between cycles of processing and sending data.

After about two weeks of testing, the copper on the wire began to oxidize, as can be seen in Figure 4. It occurred due to a chemical reaction from direct contact of wire with water. Despite this, the wire continued to conduct electricity until the day this paper was written, about two more weeks later.

Figure 4 – Wire Oxidation
Source: Authors

Some solutions for the oxidation were given:

The possibility to use a copper sheet, as a capacitive sensor, placed outside the tank, avoiding the direct contact of the electricity in the water, was raised by the authors but it would involve more complexity of assembly and maintenance by the end-user.

The ultimate idea was to drive a stainless screw through the water tank to connect the wires to water, avoiding direct contact between them. Theoretically, it would solve the oxidation problem, but no more time for testing was available. It remains as a suggestion for future tests.

Since the electric current that flows in the wire is in the order of microampere (μA), there is no concern about the risk of electric shock from putting someone's hand in the water, for example, considering the small distance between wires and the very low electric current.

Some programming methods to save energy could be used, as the ESP8266 function "deepSleep", but it would involve more electronic components, or using another microcontroller with more assets, as ESP32, for example, from the same manufacturer.

4. Discussion

As seen before, many methods to measure water level use ultrasonic sensors. Even though they are low-cost and easy-to-use sensors, this paper proposed to take advantage of water's physics characteristic to conduct electricity and indicate the level itself with no presence of third-party sensor.

The use of a photoresistor to read the variation of water reflection as made by Xueliang (2007) would imply using the ADC (Analogue-to-digital-converter) from NodeMCU, and, since it is an analogue conversion, its value could change in time due to alterations in photoresistor resistance making the maintenance more difficult.

The project observed on ("Simple Water Level Indicator Alarm Circuit Diagram", [s.d.]) uses transistors as switches and does not transmit data to anywhere; otherwise, the proposed method does not need transistors to sense the level and uses a microcontroller to send the data to the web.

Verified patent of Wei *et al*. (2016) is an interesting way of measuring water level indeed; however, it is projected to more specific applications, with large water reservoirs whose level vary according to where measurement is made and it is much more difficult to implement.

5. Conclusion

Although the searched existent methods are, usually, low-cost methods, not involving expensive technologies, the simplicity of the water level measurement and its integration with IoT differs this work to any other.

This paper had as objective to propose a low-cost method to measure and monitor water tank level, and it has proved that it is possible to make it in a simple form. The prices of ESP8266 or NodeMCU may vary, but they are between five dollars (American dollar) if imported from or bought in China, and twenty dollars on average. Resistors usually cost less than a dollar, and wires are easy to find and buy for a low price.

Internet technology has been spreading across the world in the last few years. With initiatives as "Google Station" and Facebook's "internet.org", affordable solutions tends to proliferate to reach everyone. In the digitized world, new technologies emerge to make things integrated and interconnected. As those innovations appear, low-cost devices may come up together to overcome social inequality on technological integration.

REFERENCES

Asadullah, M., & Ullah, K. (2017). Smart home automation system using Bluetooth technology. Proceedings of *International Conference on Innovations in Electrical Engineering and Computational Technologies (ICIEECT)*. April 5-7, Karachi, Pakistan.

Bonomi, F., Milito, R., Zhu J., & Addepalli, S. (2012). Fog computing and its role in the internet of things. Proceedings of *First Edition of the MCC Workshop on Mobile Cloud Computing*. August 17, Helsinki, Finland

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29: 1645–1660.

Kolz, A. L. (1993). In-Water Electrical Measurements for Evaluating Electrofishing Systems. *Fish and Wildlife Service Denver co Denver Wildlife Research Center*. Available at: https://apps.dtic.mil/docs/citations/ADA322779.

Xueliang, L. (2007). Automatic sewage collection device. CN2935119Y.

Mills, D. L. (1991). Internet time synchronization: the network time protocol. *IEEE Transactions on Communications*, 39: 1482–1493.

Pernapati, K. (2018). IoT Based Low Cost Smart Irrigation System. Proceedings of Second International Conference on Inventive Communication and Computational Technologies (ICICCT). April 20-21, Coimbatore, India.

U. S. Navy Bureau of Naval Personnel Staff. (1970). *Basic Electricity*. New York: Dover Publications.

Saha, S., & Majumdar, A. (2017). Data centre temperature monitoring with ESP8266 based Wireless Sensor Network and cloud based dashboard with real time alert system. Proceedings of *Devices for Integrated Circuit (DEVIC)*. March 23-24, Kalyani, India.

Saputra, L. K. P., & Lukito, Y. (2017). Implementation of air conditioning control system using REST protocol based on NodeMCU ESP8266. Proceedings of *International Conference on Smart Cities, Automation Intelligent Computing Systems (ICON-SONICS)*. November 8-10, Yogyakarta, Indonesia.

Severance, C. (2012). Discovering JavaScript Object Notation. *Computer*, 45: 6–8.

Singh, J. (2015). Simple Water Level Indicator Alarm Circuit Diagram. *Circuit Digest*. Available at: https://circuitdigest.com/electronic-circuits/water-level-indicator-alarm-circuit.

Wei, Y., Li, Y., Ji, G., Zhang W., & Yu M. (2016). Throwing type water level monitoring device. CN106153150 (A).

Wolf, M., & Mcquitty, S. (2011). Understanding the do-it-yourself consumer: DIY motivations and outcomes. *AMS Review*, 3: 154–170.

Yiming, X., Mahendran, V., & Radhakrishnan, S. (2016). Towards SDN-based fog computing: MQTT broker virtualization for effective and reliable delivery. Proceedings of *8th International Conference on Communication Systems and Networks (COMSNETS)*, January 5-9, Bangalore, India.