Applications of Raspberry Pi and Arduino to Monitor Water Quality Using Fuzzy Logic

Padmalaya Nayak, Chintakindi Praneeth Reddy and Devakishan Adla

Abstract Water is one of the most important natural resources that must be monitored, analyzed continuously for safety and survival of human life. The traditional method relies on collecting water samples, testing, and analyzing the water samples in specific laboratories which is not only cost effective but also causes access latency, and delay in disseminating the information among the end users. The huge growth of wireless technology and VLSI design has brought a tremendous change in developing small microsensors that are being utilized for various monitoring applications since the last decade. In this paper, an effort has been made to measure the drinking water quality with less cost in a hardware platform with the help of some water-related Sensors, Raspberry Pi, and Arduino Microcontroller. The proposed method utilizes the Fuzzy Logic algorithm and the experimental result shows that the proposed method has many more advantages over traditional systems. It is also observed that the proposed system works effectively in a real-time environment with immediate response and less cost.

Keywords WSN · Raspberry Pi · Arduino · Fuzzy logic

1 Introduction

The WSNs applications provide many challenges even though these sensor nodes are very tiny, battery operated and can be deployed randomly or deterministically to monitor the environmental parameters. The applications are huge that ranges from military, civil, health care, agriculture, disaster hit areas, water quality, and many

P. Nayak (✉) · C. P. Reddy
CSE Department, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad 500009, Telangana, India
e-mail: padma_nayak@yahoo.com

C. P. Reddy
e-mail: chpraneeth1539@gmail.com

D. Adla
CSE Department, Vidya Jyoti Institute of Technology, Hyderabad 500009, Telangana, India

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more applications [1]. It is quite amazing that the tiny sensor nodes are becoming the heart of the system design for sensing and monitoring the activities to bring Internet of Things (IoTs) into practice. Further, Raspberry Pi is a small device capable of communicating and processing having its own advantages with less cost and compact size [2] (Fig. 1). It can operate like desktop computer that starts from surfing from the Internet, playing high-definition video games, making spreadsheets, and more over huge support from online activities [3]. Figure 2 depicts the screenshot of Raspberry Pi that consists of a processor and graphics chip, memory, various connectors and interfaces for external devices. Raspberry Pi works like a standard PC, uses a keyboard and mouse (used for command entry), a power supply, and a display unit. It can also work like nonstandard version media server or smart TV. Ethernet cable is used for Internet connectivity. USB dongle can be used for Wi-Fi connectivity [2, 3]. Linux is a compatible software for Raspberry Pi and is used as an operating system for Raspberry Pi. There are several versions of Linux ported to the Raspberry Pi's BCM2835 chip, that includes Debian, Fedora Remix, and Arch Linux [4]. An operating system called Raspbian is used for Raspberry Pi. There are also many non-Linux OS operating systems available [5]. Those can be used with Raspberry Pi. One of the biggest advantages of Raspberry Pi over personal computer is that it contains some GPIO ports that can be easily connected to external

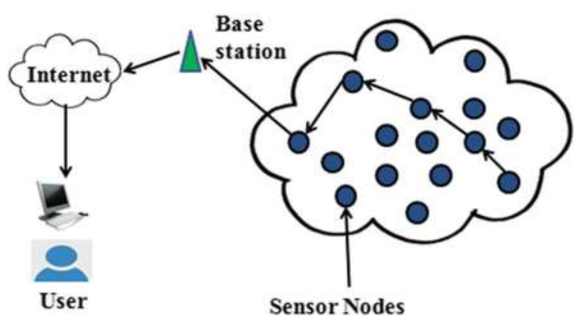

Fig. 1 Basic architecture of WSN

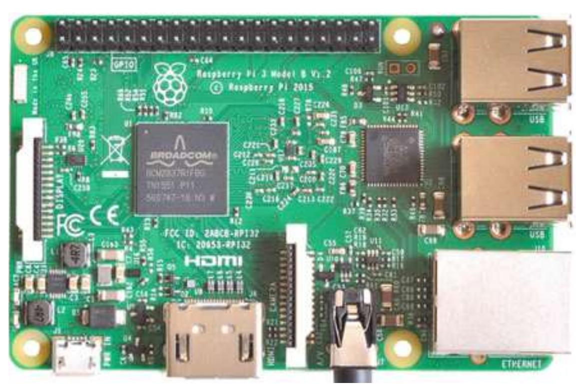

Fig. 2 Raspberry Pi

Fig. 3 Arduino UNO microcontroller

devices. In this work, Ubuntu MATE has been used for Raspberry Pi. Arduino Micro controller is another example of open source hardware on which each sensor node can be built upon with the help of the individual sensor. There are few versions of Arduino microcontroller available such as Arduino UNO, Arduino LEONARD, Arduino MEGA, and Arduino DUE, etc. In the proposed work, Arduino UNO r3 has been used. The screenshot of Arduino is shown in Fig. 3. In the proposed model, pH sensor, Conductivity sensor, and Temperature sensor has been used. Then the microcontroller is programmed to get the sensor value. Conductivity sensor model conductivity probe k 1.0 (Atlas Scientific) is used.

PT-1000 temperature kit and pH probe (ENV-40-pH) is used in our experiments. The rest of the paper is organized as follows. Section 2 presents the related work and Sect. 3 discusses about the Proposed Algorithm and Fuzzy Inference Modules. Section 4 discusses experimental results followed by the conclusion in Sect. 5.

2 Related Work

The applications of Raspberry Pi are proven in various fields. This section presents few applications. Raspberry Pi is a ticket size computer with an integrated RAM, a CPU and on chip graphical processing unit (GPU). In [6], a Raspberry Pi reads the inputs from sensors, store the sensed values in a database for historical trending and when the sensed value crosses a threshold point the output goes to the off state. In [7], the author describes that wireless sensors and a Raspberry Pi can do all possibilities in this world. In [8], the author discusses that how the small, powerful, and inexpensive sensor nodes can be used with Raspberry Pi. In [9], Raspberry Pi is used for healthcare monitoring system such as to measure the Blood Pressure and Sugar. Further, water quality measurement in an IoT environment is discussed in [10]. But no paper discusses about fuzzy logic for monitoring water quality. Motivated by this fact, we made an attempt to experiment with different sensors, Arduino and

Raspberry Pi for some applications like water quality and environmental monitoring. The main motto of this research paper is to develop a mobile application through which water quality can be monitored by pH and conductivity value of water at different temperature using fuzzy logic model.

3 Proposed Model

In this section, we have discussed the Proposed Model, Proposed Algorithms, and Experimental Set up in detail.

A. *System Assumption*

In our experiment, three sensor nodes are deployed randomly to monitor the water quality continuously. The sensors are pH sensor, Conductivity sensor, and Temperature sensor.

1. All the sensor nodes are considered to be mobile.
2. The sensors are configured into sensor nodes through Arduino microcontroller which is a programmable device and the same data can be transmitted to the Raspberry Pi.
3. Raspberry Pi has been used as a processor which can process the data and send to the cloud.
4. Temperature sensor is used to measure the environment sensor as each time conductivity changes with respect to increase or decrease in temperature.

B. *System Model*

In the proposed model, Fuzzy Logic (FL) model is used viewing that FL model can solve uncertainties involved in higher level exist in the complex real problems. As the quality of water changes with respect to various parameters, we have considered few parameters to apply the well-known Mamdani's Rule and checked the water quality. The basic Fuzzy Logic model is presented in Section D. The proposed Fuzzy Logic model is depicted in Fig. 4.

C. *Proposed Experimental Approach*

/* for monitoring the drinking water quality*/

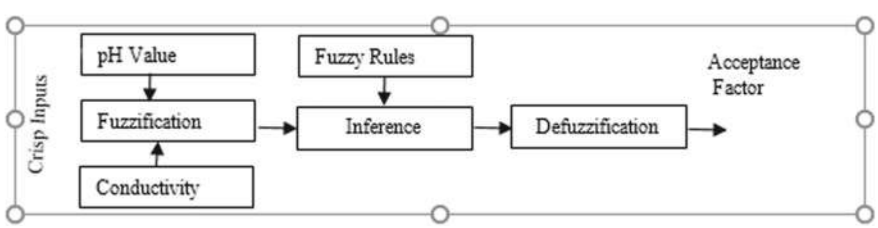

Fig. 4 Example of fuzzy logic model

1. Select some parameter to measure the water quality (Here pH value and Conductivity has been selected)
2. Use some sensors based on the parameters of your Interest (Here pH sensor, Conductivity sensor, and Temperature sensor is selected)
3. Calculate a Threshold Value
4. Water is drinkable within the threshold value
5. Apply fuzzy if-then-else rules to measure the water quality
   /* for $N_{optimal}$ Sensors */
6. All the Sensors are capable of sensing the water-related parameters
7. Send the sensed data to Raspberry Pi through Arduino Microcontroller
   /* end of for */
8. Raspberry Pi processes the data and sends the data to the Cloud
9. Fetch the data from the cloud in your Mobile Phone
   /* end of applications */

D. *Fuzzy Logic Model*

Figure 4 shows the Inference techniques and the fuzzy logic model used in our proposed model. FL model comprises four components: A fuzzifier, fuzzy inference engine, fuzzy rules, and a defuzzifier. The following procedure is required to complete the process.

1. *Fuzzifier*: Inputs/crisp values are transferred to fuzzy set.
2. *Rule Evaluation*: If-Then-Else Rule is applied here.
3. *Fuzzy Inference Engine*: Both the crisp inputs are fed, and fuzzy if-then-else rule is applied and finally, a fuzzy inference is produced.
4. *Defuzzification*: Fuzzy set values can be converted into crisp value using a defuzzifier.

In this approach, pH value and conductivity of the water is considered as two fuzzy inputs. Each input variable has individual membership function. The fuzzy set representing pH value and Conductivity is shown in Fig. 5a, b correspondingly. The linguistic variables for pH represent more, medium and less. Triangular membership is assumed for more, medium and less. For conductivity, the linguistic variables are more, moderate and less. Membership functions of all the input variables is provided

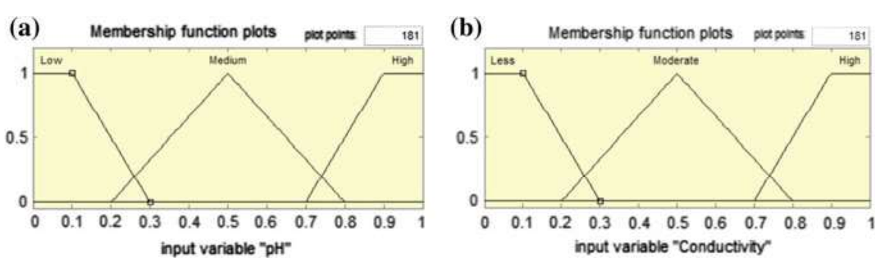

Fig. 5 Membership function plots. **a** pH value, **b** conductivity

Table 1 MF for input variable

PH value	Conductivity
Low	Less
Medium	Moderate
More	More

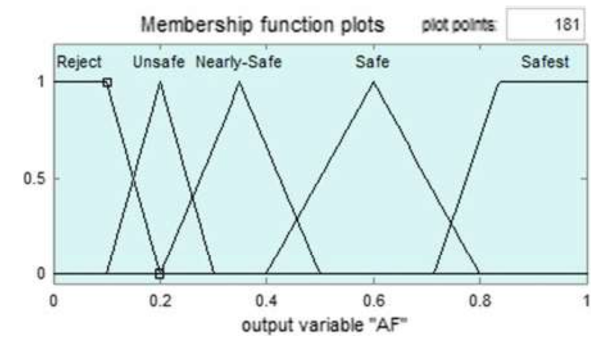

Fig. 6 Fuzzy set for output variable acceptance factor

in Table 1. For sake of demonstration, the grading of the membership function is attached with a numerical value.

Rule Base and Inference Engine: In proposed system 9 rules are taken in Fuzzy Inference Technique. Here X represents pH value, Y represents conductivity and C represents the Acceptance Factor (AF). The o/p AF is taken as 5 membership functions i.e. Reject, Unsafe, Nearly Safe, Safe and Safest. Figure 6 shows the acceptance factor.

We have derived the rules from the formula as used in Eq. (1).

$$\mathrm{AF} = \mathrm{Avg}\sum_{0}^{m} \mathrm{pH} + \mathrm{Avg}\sum_{0}^{m} \mathrm{Conductivity} \tag{1}$$

where, m varies from 0 to 5.

For the output variable AF membership function is shown in Table 2 and the Acceptance Factor (AF) value is shown in Table 3 based on Fuzzy Rules.

Table 2 MF for output variable AF

Membership functions
Acceptance factor
Reject (0), Unsafe (1), Nearly safe (2), Safe (3), Safest (4)

Table 3 Fuzzy rules and value of AF

pH Value	Conductivity	AF for drinking water
More (2)	More (2)	Safest (4)
Medium (1)	More (2)	Safe (3)
Low (0)	More (2)	Nearly safe (2)
More (2)	Moderate (1)	Unsafe (1)
Medium (1)	Moderate (1)	Nearly safe (2)
Low (0)	Moderate (1)	Unsafe (1)
More (2)	Less (0)	Nearly safe (2)
Medium (1)	Less (0)	Unsafe (1)
Low (0)	Less (0)	Reject (0)

4 Results and Discussion

A. *Experimental Set Up*

In our experiments, we have used one Raspberry Pi, Arduino and some sensors like pH sensor, Conductivity sensor and Temperature sensor. One bread board is used for multi-point input/output connections. The pH and Conductivity sensors are used to sense the water quality and send the data to Raspberry Pi through Arduino. The complete experimental set up is shown in Fig. 7a, b. Figure 7a shows the experimental set up for drinking water whereas 7b shows the experiment set up for mud/ground water. We have implemented Fuzzy Logic Algorithm and the code has been dumped into the Raspberry Pi to measure the water quality. The output is monitored in a monitor. The same value can be uploaded to the remote cloud and it can be accessed through the Mobile Phone when the system is not in use. To avoid the connectivity between sensors and breadboards, high quality wireless senor motes can be used.

B. *Results and Discussions*

The quality of drinking water is verified through Mamdani's Fuzzified Rule as discussed in Table 3. Two inputs such as pH value and conductivity are given as the

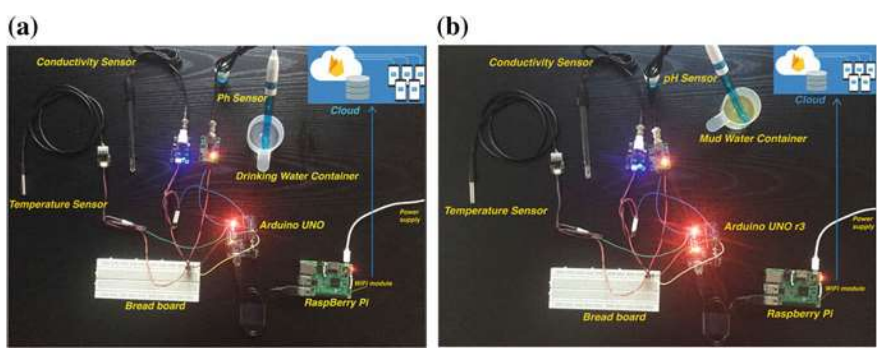

Fig. 7 **a** Experimental set up for drinking water, **b** for mud/ground water

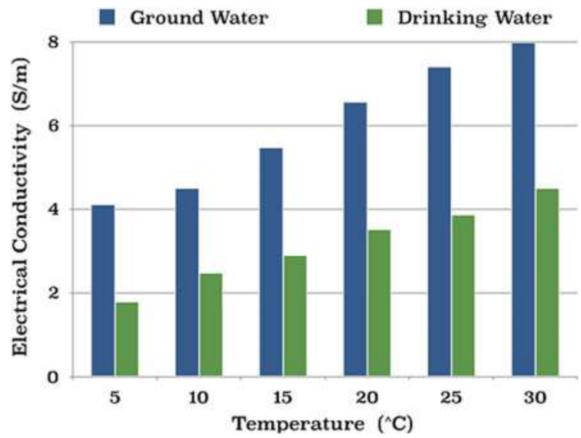

Fig. 8 Temperature versus conductivity

fuzzy inputs. We have verified the AF for drinking water with 9 conditions using Mamdani's rule through MATLAB. The same information can be fetched from the remote cloud to our mobile phone. Figure 8 shows the relationship between conductivity and environmental temperature. When temperature increases, conductivity increases proportional to the temperature. We have taken two samples of water such as mud water and drinking water. When the temperature reaches at temperature 250, the conductivity increases to 7.8. Whenever the temperature reaches below 130, conductivity decreases, and the water is not drinkable because the optimal value of conductivity for drinking water lies in between 6.7 and 7.8.

5 Conclusion

The summary of the paper concludes that an efficient Wireless Sensor Network application has been developed with the help of some water-related sensors, Raspberry Pi and Arduino. Drinking Water quality can be monitored on our mobile phone by fetching the information from the remote cloud with less cost and less overhead. Two important parameters of water such as pH value and electrical conductivity has been considered and Mamdani's rule has been applied to check the drinking water quality. The technical novelty of the paper emphasizes on Wireless Sensor Network applications that utilizes the principle of fuzzy logic control to monitor the drinking water quality. It has been proven that fuzzy logic control handles the real-time problems more accurately and effectively than any other traditional model.

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