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Monitoring and Controlling System of Water Quality and Temperature in a Coffee Pot

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The quality of brewed coffee is characterized by its multisensory attributes such as smell, taste, and flavor, which are affected by water quality and brewing temperature. Thus, maintaining the quality of brewed coffee is important. In this study, a control system that incorporates long-range radio (LoRa) technology for monitoring total dissolved solids (TDS) and temperature, and for controlling water levels in the coffee pot is developed. The system includes a LoRa module for data transmission without the Internet and sensors for monitoring the parameters and sending out warnings with indicators. Data on the parameters are transmitted to a remote server (a PC) and stored on the server as an Excel file. The information on the remote server can be shared with users and administrators through the Internet. The coffee pot is controlled remotely using the server's user interface. The developed coffee pot can maintain the quality of brewed coffee, and thus will be helpful to improve the service quality of hotels and restaurants.

1. Introduction

Coffee is the most consumed beverage and one of the most sold foods in the world. According to the report from the International Coffee Organization (ICO), the world coffee consumption rate reached 152.2 million 60 kg bags of coffee beans in 2015 and has shown an average annual growth rate of 2.0% since 2011.(1) Coffee brewing is a solid–liquid extraction where hot water is poured into roasted and ground coffee beans. In brewing coffee, water is the solvent for extracting dissolved compounds or suspended solids, which affect the sensory properties of coffee.(2) Such properties are determined by the coffee bean species, the storage, grinding, and roasting methods of coffee beans, and the brewing method.(3–5) One important factor that affects the multisensory perception of brewed coffee is the quality of the brewing water, which depends on the content and composition of substances in the water.

The quality of water is usually represented by its total hardness and alkalinity. Total hardness is defined as the amount of calcium and magnesium at equivalent concentrations.(6–10) The

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European Specialty Coffee Association (SCAE) defines the upper and lower hardness limits to be 175 and 50 ppm of $CaCO_3$ in water.(11) The total hardness of water directly affects the taste of water and the palatability of brewed coffee(12) as coffee is prepared in few minutes using hot water close to the boiling point.(13) In addition to the total hardness, the temperature of the brewing water is also important to the taste of brewed coffee.(14) With the increasing demand for coffee with unique taste and flavor, cold-brew coffee, which is prepared using water at a temperature of 20–25°C or lower, has gained much popularity recently, but a longer brewing time from 8 to 24 h is required.(13,15)

To brew coffee with a satisfying taste and flavor, it is important to maintain constant water quality and temperature. Therefore, we developed a coffee pot monitoring system with a long-range radio (LoRa) module in which sensors are used to control the temperature, quality, and amount of water.(16) Via LoRa, the data on the status of the coffee pot is transferred through a server to the system that maintains the taste and flavor of brewed coffee. The system can be used at hotels and restaurants that desire to serve customers good-quality coffee.

2. Structure of the System

In the coffee pot control system, three sensors and warning indicators for monitoring water temperature, total dissolved solids (TDS), and the water level in the pot are used. The sensors installed inside the coffee pot are connected to the server to transmit the sensor data to a personal computer (PC), which acts as a server, as shown in Fig. 1 and Table 1. The warning indicators are turned on to indicate abnormal water levels, TDS, and water temperature, and are also shown on the user interface of the PC. The heating module is automatically turned off when the water temperature reaches the preset temperature, which can be set on the PC. To monitor water quality, a TDS sensor detects the water hardness. Detected TDS values are forwarded to the PC, and a warning indicator light is activated when the water hardness exceeds the preset value. An instruction for changing the water in the coffee pot is also shown on the user interface. The

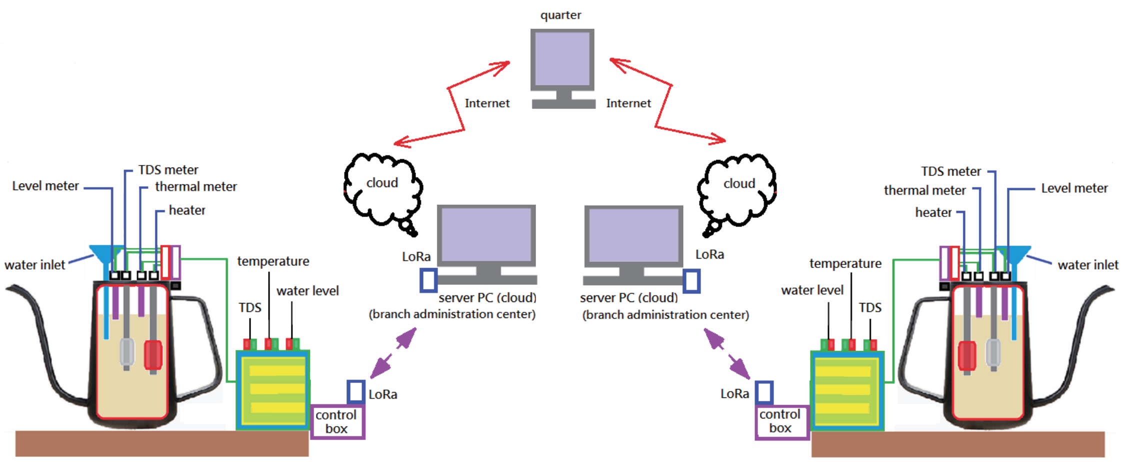


Fig. 1. (Color online) Coffee pot control system developed in this study.

control logic for water level, temperature, and TDS is illustrated in Fig. 2. All the information on water level, temperature, and TDS is recorded in an Excel file on the server.

Table 1
Sensors used in developed coffee pot control system.

Sensor	Specification	Model/Manufacturer
Water temperature	Input voltage: 3.0–5 V Temperature range: −55–125 °C Accuracy: ±0.5°C from −10 to 85°C Waterproof Converting 12-bit temperature to digital word in 750 ms (maximum) User-definable and nonvolatile temperature alarm settings 1-wire interface and one port pin for communication Probe is 7 mm in diameter and 26 mm long	426-KIT0021/Mouser Electronics
TDS	Input voltage: 3.3–5.5 V Output voltage: 0–2.3 V Working current: 3–6 A TDS measurement range: 0–1000 ppm TDS measurement accuracy: ±10% F.S. (25°C) Module size: 42 × 32 mm Module interface: pH 2.0–3 Electrode interface: XH2.54-2P	TDS Meter 1.0 /DFROBOT
Water level	Operating temperature: 0−100°C Floating long tube made of stainless steel 304 Drainage alarm and other functions	(X-4) 304 stainless steel float switch/ UCI Electronics

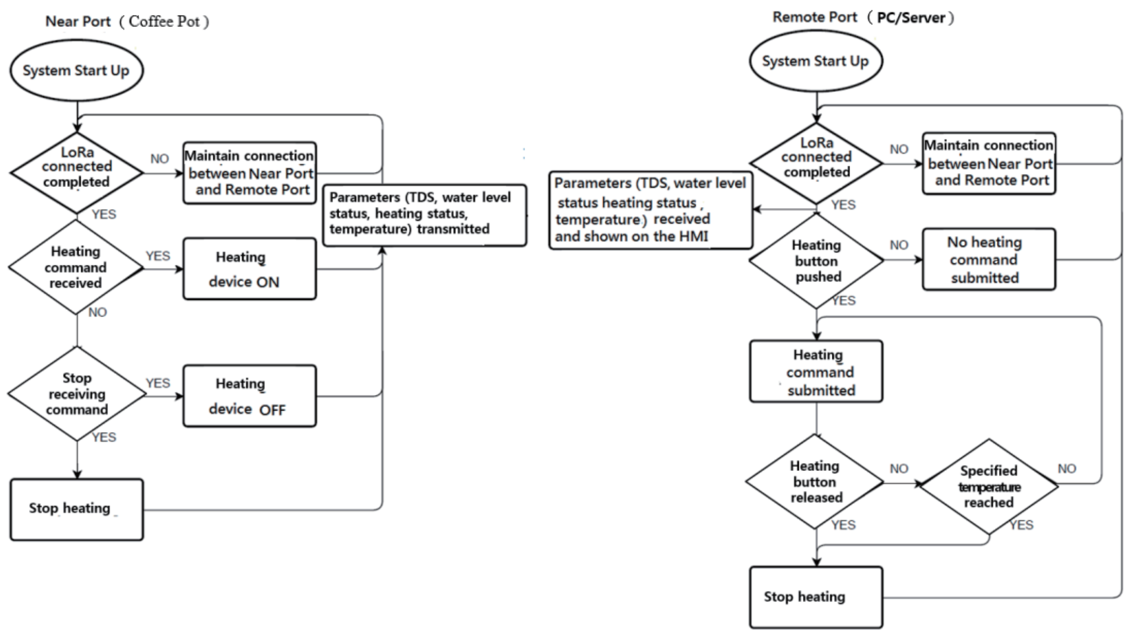


Fig. 2. Control logic of coffee pot control system including PC as server.

Arduino is used for the LoRa module with a coded program, as shown in Fig. 3. The human–machine interface (HMI) in the PC is programmed using C#. An abstract of the C# program is shown in Fig. 4, and the HMI is designed as presented in Fig. 5. The values of TDS, water level, and temperature are shown, and the heating module is controlled via the HMI.

We design the control system to be operable without Internet access. Therefore, remote data communication is required. Because of its low electrical power consumption and long

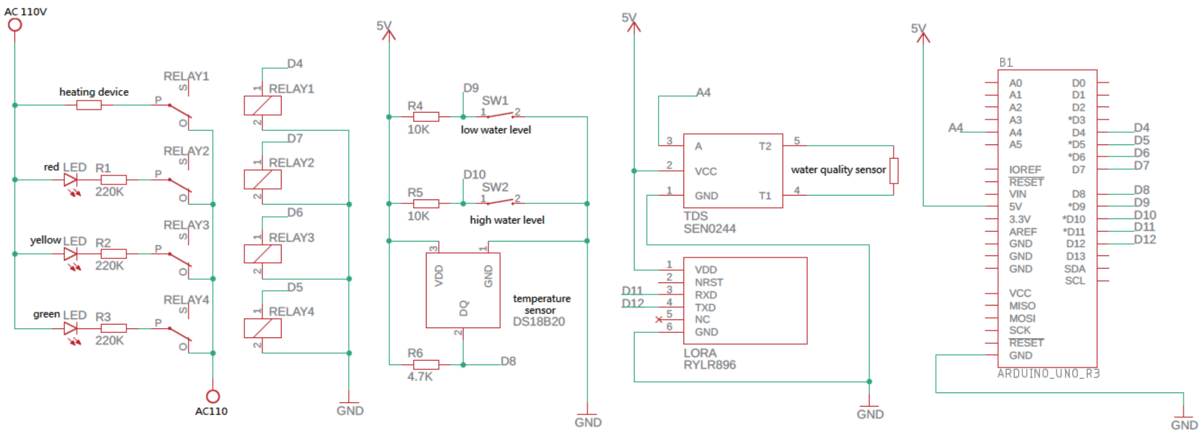
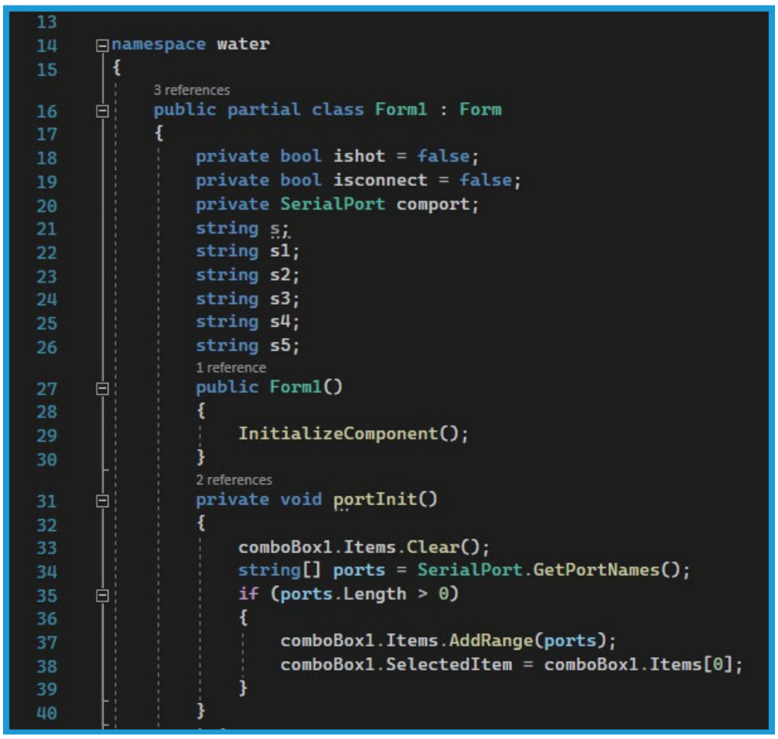


Fig. 3. (Color online) Wiring diagram of LoRa module with Arduino.



```
namespace water
{
    3 references
    public partial class Form1 : Form
    {
        private bool ishot = false;
        private bool isconnect = false;
        private SerialPort comport;
        string s;
        string s1;
        string s2;
        string s3;
        string s4;
        string s5;
        1 reference
        public Form1()
        {
            InitializeComponent();
        }
        2 references
        private void portInit()
        {
            comboBox1.Items.Clear();
            string[] ports = SerialPort.GetPortNames();
            if (ports.Length > 0)
            {
                comboBox1.Items.AddRange(ports);
                comboBox1.SelectedItem = comboBox1.Items[0];
            }
        }
```

Fig. 4. (Color online) Coding in C# for LoRa module of PC of coffee pot control system.

transmission distance (2–5 km),[15] the LoRa-based remote data communication method is adopted, as shown in Fig. 1.

3. Results and Discussion

In the control system, a TDS sensor, a water temperature sensor, a water level sensor (Table 1), and four actuators (i.e., a heating device and three indicators) are used. Data on the TDS, water level, and temperature are transmitted to the PC. Users operate the system, such as replacing and replenishing water and heating the coffee pot, in accordance with the data. Warning indicators for the level, TDS, and temperature of the water are turned on if the measured values deviate from the preset values. When the values in the pot are appropriate for brewing coffee, green lights are turned on, while red lights indicate inappropriate values. With such warnings, users can maintain the quality of brewed coffee. The prototype of the system is shown in Fig. 6.

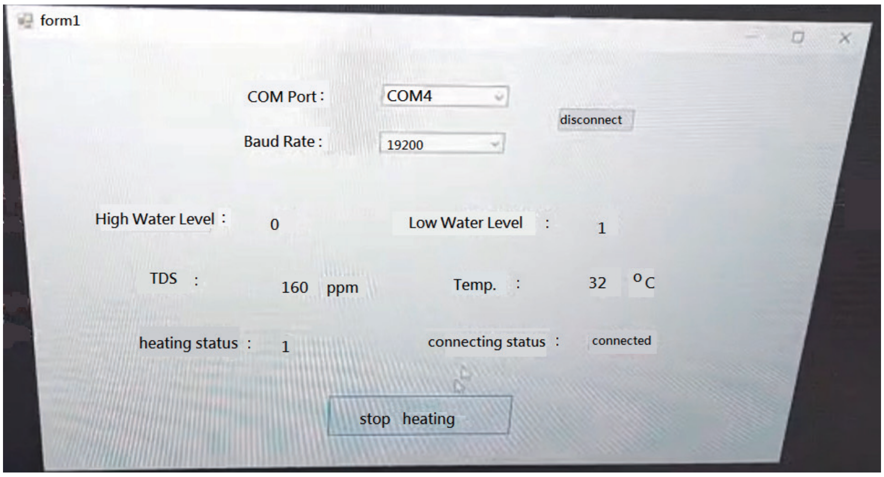


Fig. 5. (Color online) HMI of PC used as a server.

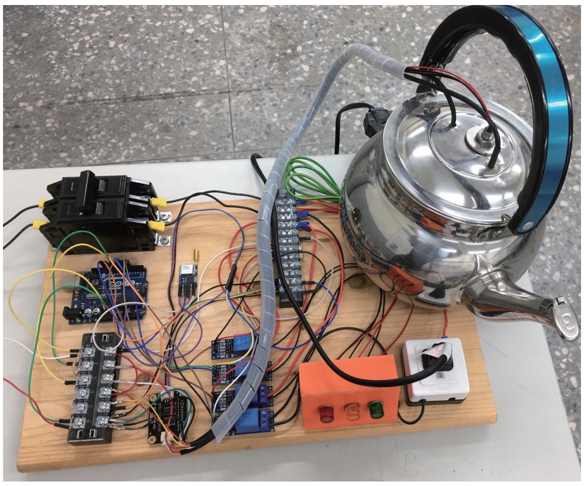


Fig. 6. (Color online) Prototype of coffee pot control system.

4. Conclusions

Water quality and temperature are crucial when brewing coffee. Therefore, it is necessary to monitor and control water quality and temperature to maintain the best flavor and taste of brewed coffee. Thus, we develop a system for controlling the water quality, level, and temperature in the coffee pot. The system adopts sensors to monitor the water level, TDS, and temperature. All values detected by the sensors are transferred to a PC (a server) for monitoring and controlling the system. Warnings are given by red lights in the system and are shown on the PC. A LoRa module is used to connect the coffee pot system and the server as it does not need an Internet network and operates at a low electrical power for a relatively long transmission distance. All data from the system are stored on the PC as an Excel file so that the previous data can be queried at any time. The PC can be connected to mobile devices through the Internet. The proposed LoRa-based coffee pot control system can be used to provide better service at restaurants and hotels.

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