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SMART COFFEE VENDING MACHINE BASED ON IOT CONCEPT

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Abstract. *In order to improve the effectiveness of franchise system, this paper describes how to utilize the Internet of Things (IoT) concept for upgrading a franchisor's traditional coffee vending machine to be a smart coffee vending machine (SCVM) with remote monitoring and control capabilities. The IoT-based SCVM provides powerful web dashboard to monitor machine operation statuses, track ingredient and component availability, and adjust hot drink recipes. The proposed improvement can therefore help both franchisor and franchisee not only to ensure that how well the machine is operating, and how well the machine is stocked but also to plan that when a supply worker needs to pay a visit to the machine for refilling ingredients based on sales data, and when a maintenance worker needs to pay a visit to the machine for providing services based on technical data. The proposed technique uses an Arduino board to replace an existing machine controller and installs a Raspberry Pi module to perform as a gateway for data transmission between the SCVM and the Ubidots cloud server via Internet. The Node-RED engine running on the Raspberry Pi is utilized as the IoT platform to collect and process the technical and sales data of the SCVM that dispenses three kinds of hot drinks. Based on user login system, the franchisor is allowed to remotely monitor the interested parameters of all SCVMs on the created dashboard for ensuring product availability as well as to remotely control the ratios of instant coffee/cocoa powder and hot water for ensuring product quality, whereas each franchisee is allowed to remotely monitor the operation status and daily sales detail for his approved machines only. Test results from data simulations confirm that the upgraded SCVM and created dashboard subpages function correctly in accordance with the franchisor's requirements.*

Keywords: Arduino board, Coffee vending machine, Dashboard, Franchise system, IoT, Raspberry Pi module, Ubidots cloud service

1. **Introduction.** Nowadays, coffee vending machine business becomes one of major sectors in ever-developing coffee market. Compared with the costs of coffee shops, the great temptation of this business for investors is possibly that it embodies the lower initial investment with shorter payback period. However, there are various key factors to help vending machine business to succeed. For example, the vending machine should always be in its normal operating condition. The requested drinks should always be available. The machine should provide the right mix of drinks in the right order, and customers should be able to receive the ordered drinks. Recently, a smart coffee vending machine providing indoor environmental data available to customers by utilizing Android-based smartphone application has been introduced [1]. Based on sensor and actuator networks installed inside the machine, the customer can adjust the ordered coffee drink taste and check the material mixer detachment status, which is considered to be the cleaning status of the machine. In addition, a method to identify two significant anomalies in a liquid-coffee

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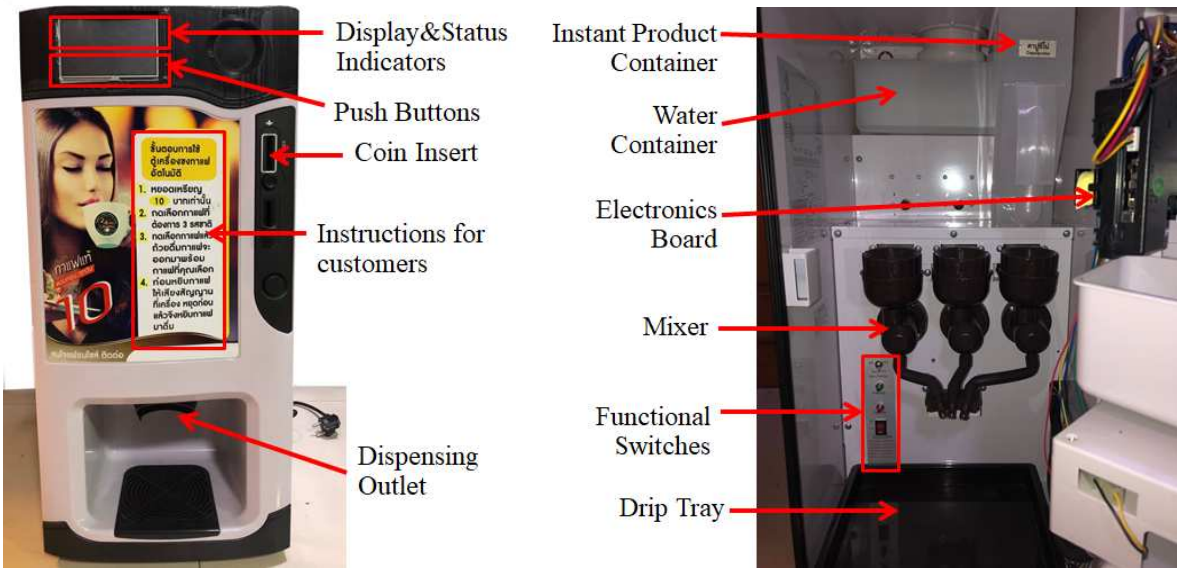
vending machine by employing feature analysis of electrical current waveforms in brewing process for a cup of coffee has been described [2]. The target anomalies that cause degradation of product quality and quantity include internal water leakage and lack of coffee bean supply in the vending machine. In order to improve problem-solving and decision-making processes at factory sites, the techniques based on supervisory control and data acquisition (SCADA) software to make field device data available to condition monitoring have been proposed [3-5]. Alternatively, interesting techniques for system implementation of data acquisition and monitoring of key performance indicators in manufacturing operations for continuous quality improvements by using web services have been presented [6,7]. To reduce unplanned downtime of factory equipment, a remote monitoring and alerting system using low-cost IoT platform has been also described [8]. Moreover, utilizing cloud technology for data storage and decision making to realize industrial supervisory system has been introduced [9]. Users are able to access plant information stored in the cloud database through web pages. Because of their advantages, this paper applies the ideas of Internet-based remote supervisory systems to coffee vending machine franchise, which is one of common business patterns for brand promotion. The aim of this paper is to present a technique for upgrading an existing coffee vending machine modeled BD.24CPM-3 [10] to remotely share its operating conditions and sales data via cloud dashboard application. The proposed technique is based on IoT concept to help the franchisor and franchisee to plan maintenance tasks and raw material stocks as well as to understand the preferences and behaviors of their customers.

The rest of this paper is organized as follows. Major specifications of the studied existing coffee vending machine before improvement are described in Section 2. The proposed technique to upgrade the existing machine capabilities and the test results are shown in Section 3 and Section 4, respectively. Finally, conclusions and possible future work are stated in Section 5.

2. **Studied Existing Coffee Vending Machine.** Figures 1(a) and 1(b) show the main parts outside and inside the coin-operated coffee vending machine modeled BD.24CPM-3, respectively. The length, width, and height dimensions of the machine are 43cm, 49cm,



(a) Outside (b) Inside

FIGURE 1. Studied coffee vending machine modeled BD.24CPM-3

and 31.5cm, respectively. Thus it takes up the space less than one square meter in the form on desk or on floor. This machine accepts only a 10-bath coin and uses push buttons for menu selectors. The display shows the messages during normal operation mode. In addition, four indicator lights for 'ready' status, 'heating operation' status, 'empty cups' status, and 'low water level' status are also provided. However, these message displays and status indicators are locally monitored. The machine with automatic cup dispenser can produce three types of hot beverages such as espresso, cappuccino, and cocoa from three different types of instant drink powder in product containers. Instant beverage products are directly supplied from the franchisor. Four functional switches installed inside the machine are provided for setting up the machine, cleaning the mixer, testing the cup dispenser, and powering the water heater. After inserting the coin and by pressing the button for the selected item, the programmed beverage is dispensed into a 6-ounce paper cup. All purchase transactions of the machine are automatically recorded. However, the franchisor can access these sales data when physically visiting the machine only. In addition, the maintenance and restocking services offered by the franchisor are usually based on calendar schedules.

3. **Proposed SCVM for Franchise System.** To alleviate limitations for managing the franchise business, the IoT-based technique to enhance the remote monitoring and control capabilities of the studied vending machine can be described as follows.

3.1. **Proposed technique for upgrading the studied machine.** Figure 2 illustrates a block diagram for the proposed enhancement technique. To upgrade the functions of the studied coffee vending machine of Figure 1, the previous push-button interface and electronic board are replaced by the new graphic touchscreen and Arduino Mega microcontroller, respectively. The previous functional switches installed inside the machine are still available for hardware configurations and maintenance purposes. The touchscreen offering serial-networking feature can directly connect to the Arduino Mega microcontroller, which is the machine controller. The Raspberry Pi module is installed for data transfers between the upgraded vending machine and the Ubidots cloud server via Internet. The Node-RED processing on the Raspberry Pi is defined as the IoT device using message queuing telemetry transport (MQTT) protocol. The Arduino Mega board and the Raspberry Pi module operate and communicate together through the Modbus RTU protocol. Thus, the Raspberry Pi module functions as the gateway that converts from the Modbus RTU protocol to the MQTT protocol and vice versa. For automatic operations of the proposed SCVM, Figure 3 depicts the flowchart diagram to run the main program loop, while Figure 4 depicts the flowchart diagram to run one of subprograms in the machine controller to brew the selected beverage. The key parameters including the availability of water in container, availability of product powder in container, and availability of the

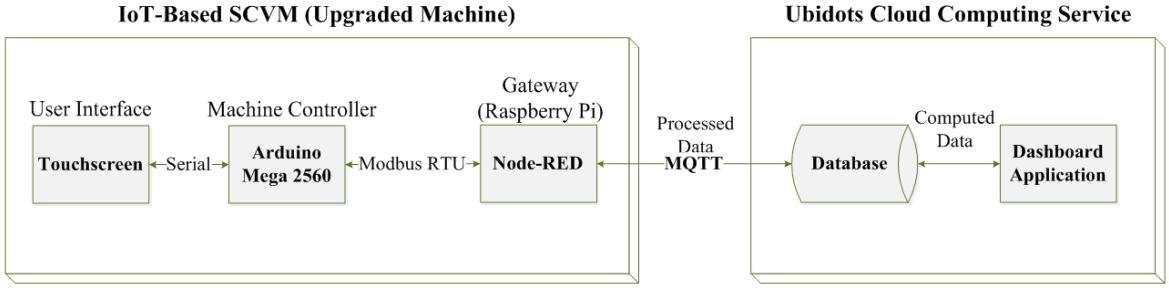


FIGURE 2. Block diagram of the proposed enhancement method

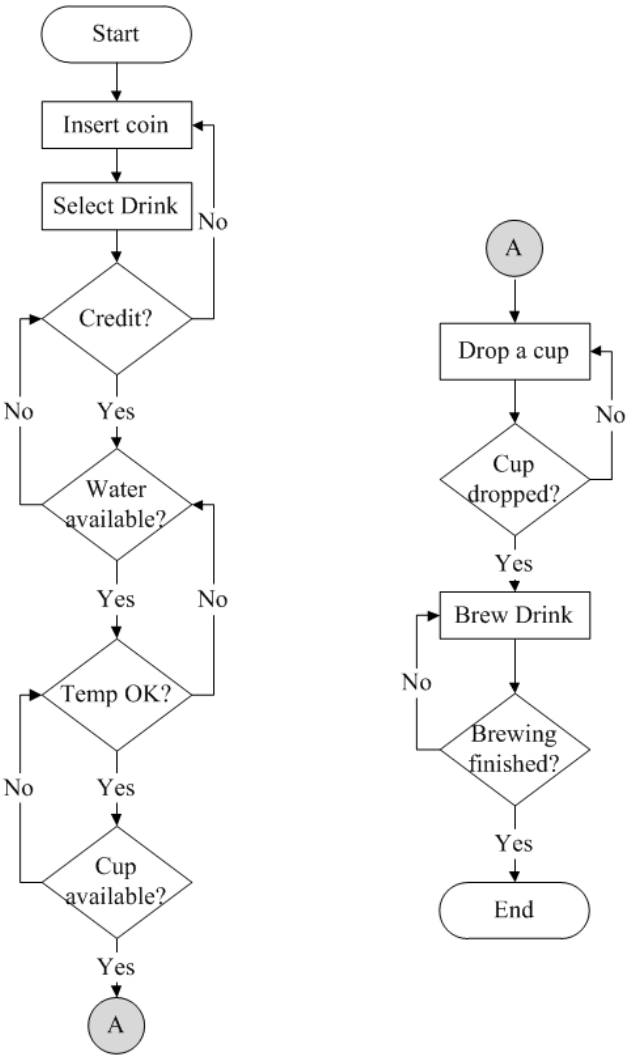


FIGURE 3. Flowchart diagram of the SCVM controller to run the main program loop

cup in dispenser are required to be monitored to ensure the machine operation status. The temperature of hot water as well as the ratios of instant powder and hot water for brewing the beverages can be controlled to ensure the consistency in quality and taste of products. After inserting the 10-bath coin, the customer can choose the beverage menu and check the machine operation status from touchscreen displays. To produce the selected beverage, the electromagnetism valve is utilized to pour or intercept hot water into the cup. The feeding motor is used to discharge the instant drink powder, while the stirring motor is used to stir the instant drink power into hot water. The machine operation parameters and purchase transactions are recorded in the Arduino Mega board. Figure 5 shows the Node-RED editor for flow-based programming to automatically transfer the recorded data to the Ubidots cloud computing server. To provide gateway function, the Node-RED Modbus node properties such as function code and address are required to be configured as shown in Figure 6(a). Similarly, the Node-RED MQTT node properties such as server and port are required to be configured as shown in Figure 6(b). To save space, Table 1 summarizes some technical and sales data of the proposed SCVM, which are specified to be monitored and controlled on the main and subpages of the created Ubidots dashboard in real time.

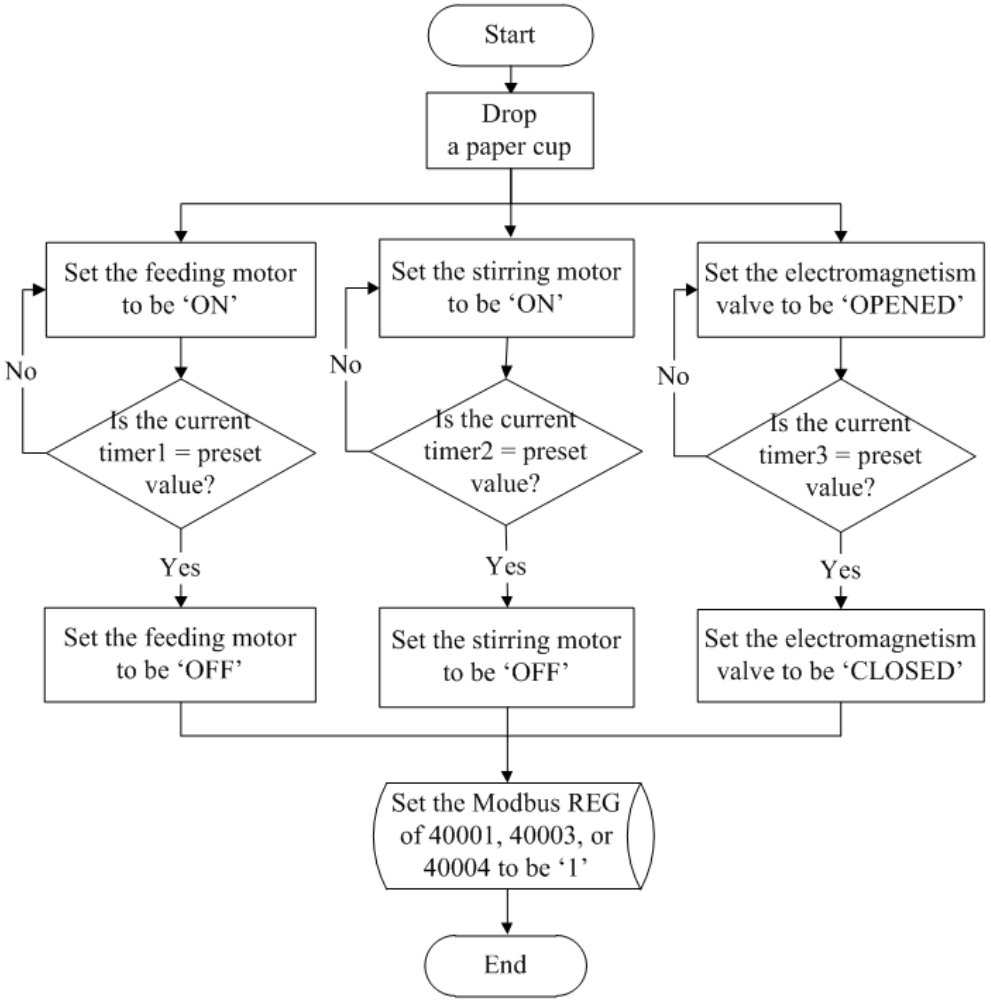


FIGURE 4. Flowchart diagram of the SCVM controller to brew the selected beverage

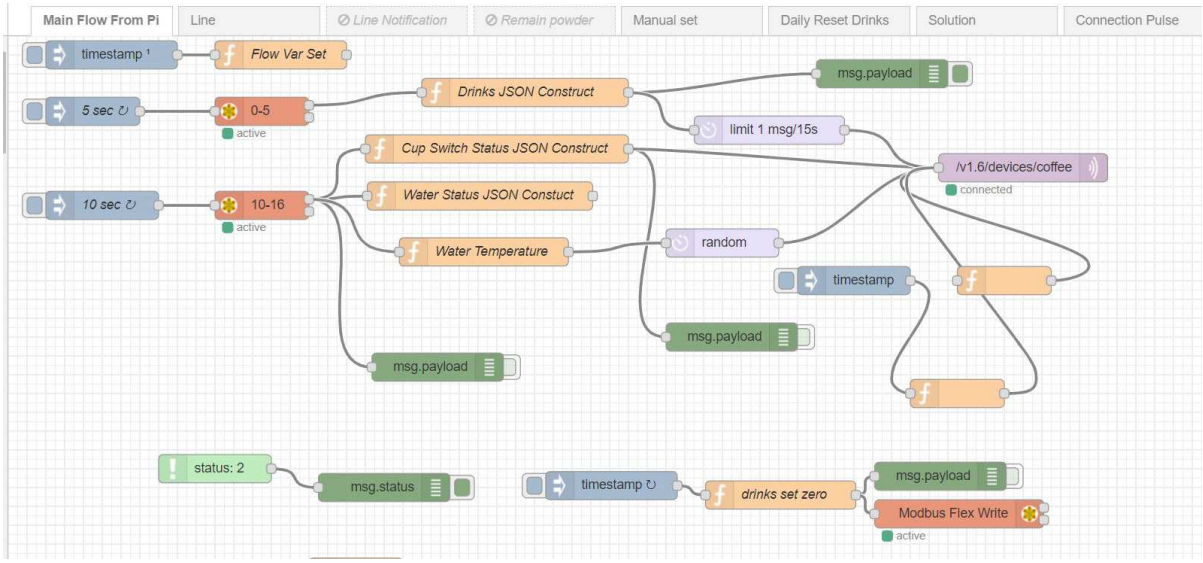
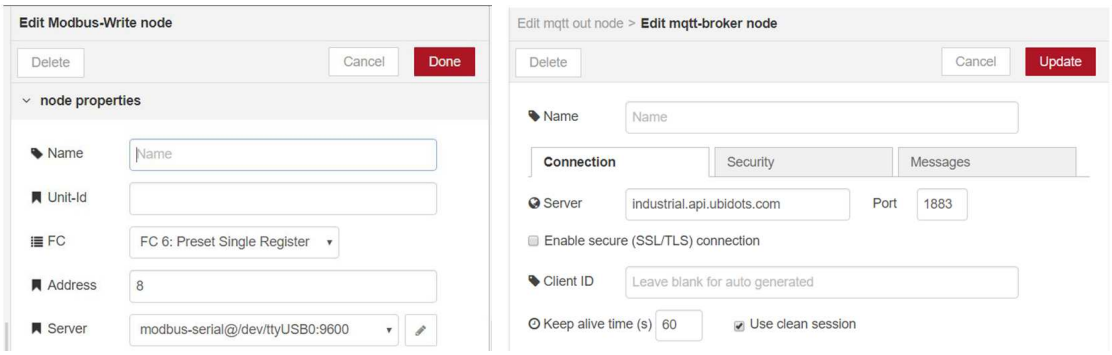


FIGURE 5. Node-RED flow-based programming for the proposed SCVM



(a) Modbus node (b) MQTT node

FIGURE 6. Configuring the Node-RED to provide the gateway function

TABLE 1. Some specified data to be monitored and controlled on the created dashboard

Parameter	Description
cup_status	Raw variable for displaying the availability of the cup in dispenser, where '1' and '0' denote 'available' and 'unavailable', respectively.
water_temp_status	Raw variable for the actual temperature of hot water.
water_solution	Raw variable for controlling the ratio between instant product powder and hot water.
drink1	Raw variable for sales data of drink1 (such as espresso), it becomes '1' for successful transaction of drink1.
drink2	Raw variable for sales data of drink2 (such as cappuccino), it becomes '1' for successful transaction of drink2.
drink2	Raw variable for sales data of drink3 (such as hot cocoa), it becomes '1' for successful transaction of drink3.
sum_drink1_1D	Synthetic variable for calculating the daily sales data for drink1.
sum_drink2_1D	Synthetic variable for calculating the daily sales data for drink2.
sum_drink3_1D	Synthetic variable for calculating the daily sales data for drink3.
sum_drink1_1m	Synthetic variable for calculating the monthly sales data for drink1.
sum_drink2_1m	Synthetic variable for calculating the monthly sales data for drink2.
sum_drink3_1m	Synthetic variable for calculating the monthly sales data for drink3.

3.2. **IoT-based SCVM installation concept for franchise system.** Based on the remote monitoring and control capabilities of the SCVM, the installation concept for franchise business is shown in Figure 7. The franchisor and franchisees can access the technical and sales data via the created web dashboard by employing user login system. In order to ensure that hot drinks are always available to offer customers, the franchisor can monitor the real-time operation statuses of all SCVMs, which are connected into the cloud computing service. In addition, the ingredient and component availability and the drink recipes of each SCVM can be tracked and adjusted, respectively. However, the franchisee is allowed to monitor the operation status and daily sales data for his approved machines only.

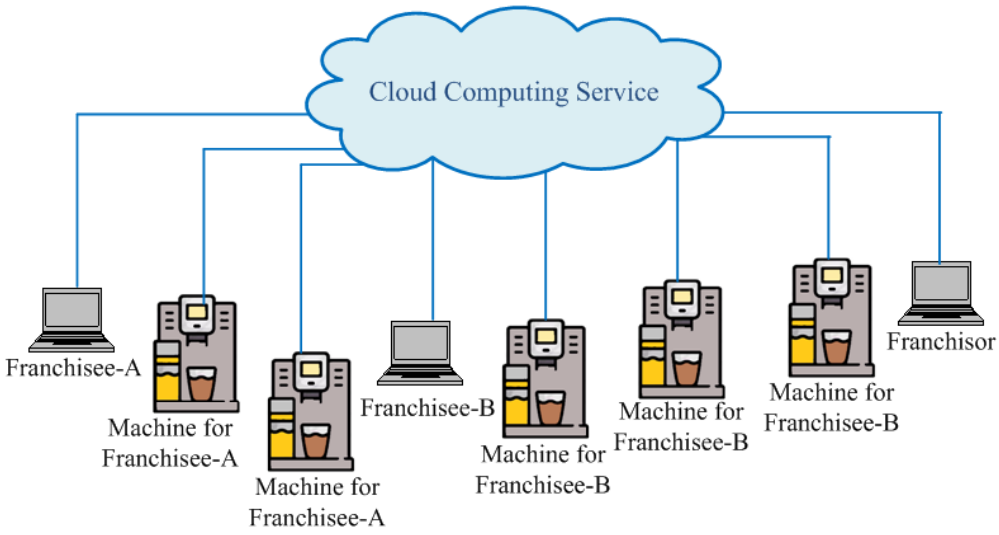


FIGURE 7. Network architecture for installing the SCVMs for franchise business

4. **Test Results.** Based on data simulations, Figure 8 shows the created dashboard subpage to display the interested technical parameters including the water availability, the cup availability, and the instant powder availability for the SCVM operation. In addition, the daily purchase transactions for each drink product and the total of daily sales are also monitored. Figure 9 shows the created dashboard subpage to display the monthly sales data.

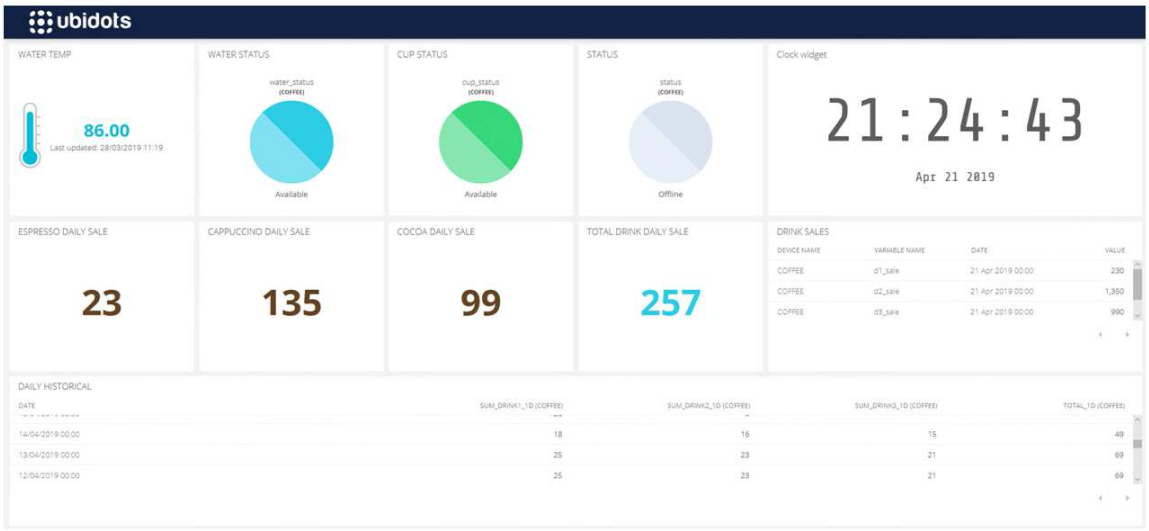


FIGURE 8. Dashboard subpage to display the technical and daily sales data of the SCVM

5. **Conclusions.** A technique based on IoT concept to enhance the remote monitoring and control capabilities of the existing coin-operated coffee vending machine of the franchisor for franchise development has been presented. Test results verify that the specified technical and sales data of the upgraded coffee vending machine can be tracked remotely on dashboard in real time. Therefore, the proposed technique can support both franchisor and franchisee to prevent the problems in maintenance and restocking services. Upgrading the proposed SCVM with added functions such as automatic cleaning and mobile payment is the future work.

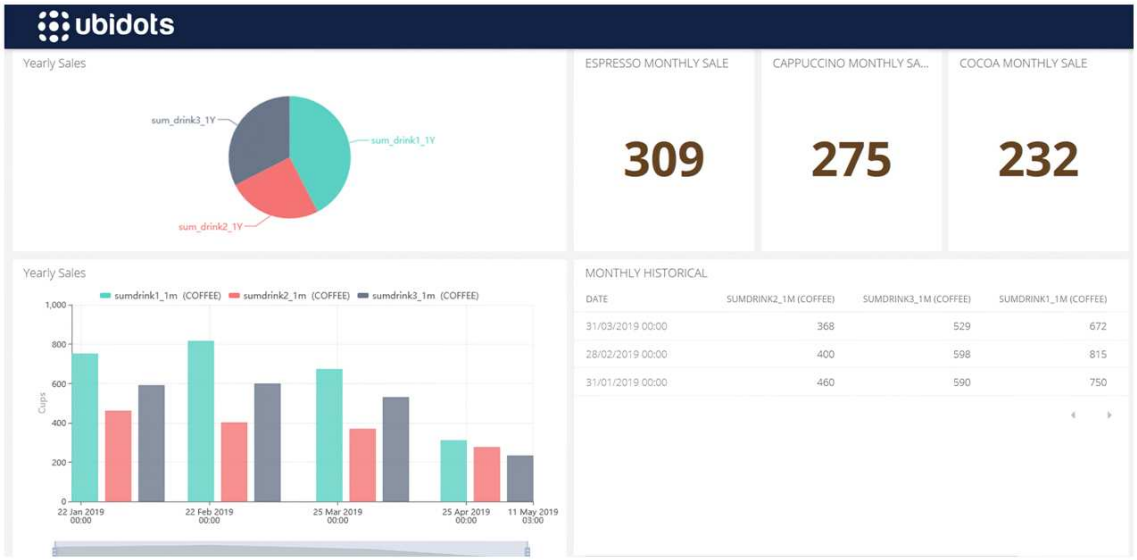


FIGURE 9. Dashboard subpage to display the monthly sales data of the SCVM

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