IoT Based Temperature Control for Smart Mosque

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Abstract. Malaysia is a country which has one of the biggest Muslim societies in the world, followed by a large number of mosques scattered in various places and these mosques have maintenance problems especially in energy consumption. Mosques normally experience sudden influx of users at five specified times throughout the day, and the use of the fans in the mosques is very inefficient and wasteful, corresponding with the five daily Islamic prayers. Regarding this matter, this project is conducted in order to reduce mosque energy consumption by developing smart mosque temperature control. The temperature control aims to focus on reading the temperature of mosque and then smartly controls fan according to the temperature reading by applying Internet-of-Things (IoT). The Arduino Uno controller board will read and process the sensors to trigger the fan switch. The act of controlling the fan according to the ambient temperature of the mosques will help to reduce power consumption. The smart mosque temperature control can be applied widely in Malaysia to make mosques smarter and efficient in energy consumption.

1. Introduction

Internet-of-Things (IoT) is a system of related computing devices, mechanical and digital machines that are provided with limited identifiers and the ability to transfer data over a network without demanding human-to-human or human-to-computer interaction [1]. Connected security systems, thermostats, cars, electronic appliances, and vending machines are examples of objects in the IoT ecosystem. IoT enables humans and computers to learn and interact with billions of things that include sensors, and actuators, which can provide a variety of solutions in different sectors such as health [2], agriculture [3] and public buildings [4]. In the aspect of public buildings, mosques face a number of challenges, such as electricity bills, water bills, and maintenance. A prime example is the inefficient use of air conditions and power consuming fans which causes the electricity bills to be high while wasting energy. Moreover, the heat generated from the lights requires more air conditioning and more fans for cooling, hence contributing to a higher electricity bill. Thus, there is a need for a technology that can be used to address these challenges in mosques. IoT is the most suitable candidate because it is the enabling technology for real-time and autonomous machine-to-machine (M2M) or device-to-device (D2D) communication that can transform a conventional system into a smart one that is low cost as well as energy saving.

Managing a mosque’s temperature especially when the weather outside is very hot or cold without wasting energy while providing comfort to about 500 worshippers during the five daily prayer times is a difficult task. Moreover, providing a comfortable place to worship requires the air conditioning to be
switched on continuously which causes considerable energy wastage during prayer times. Temperature management systems such as smart thermostats are used to overcome the aforementioned problem. Examples of such systems are offered by Honeywell, Ecobee, and Nest Labs [5].

2. Literature Review

The author in [6] developed an automatic room temperature control system with a security system for controlling the temperature in server rooms, especially those that are poorly ventilated and have no cooling units. The automatic room temperature control consists of temperature sensors which used to detect the temperature of the server room and a controller. More specifically, the controller switches on the cooling system which is made up of a set of brushless fans when the current temperature exceeds the set-point temperature. The server room will be cooled by the fans until the current temperature drops down below the set-point temperature. The ON/OFF state of the fans depends on the readings from the PIC Microcontroller [7]. The added security system is perceived as a secondary system that regulates access to the server room door by demanding an access password to open the door. The system is built with a temperature sensor that is placed in the server room that detects the current temperature and displays the value on an LCD screen.

The Temperature Control System and the Security System are designed to function independently of each other. Thus, the failure of one of the systems does not affect the functionality of the other.

2.1. Thermal Comfort in Mosque

Thermal Comfort is essential in providing a healthy indoor living, quality of life in the urban environment, and reduces energy consumption. Thermal comfort is a condition of mind that expresses satisfaction with thermal [8]. There are six factors that affect thermal comfort and grouped mainly into two; environmental and personal. The environmental factors are air temperature, radiant temperature, air velocity, and humidity. The personal factors are clothing insulation and metabolic heat. These factors contribute to human thermal comfort.

The thermal comfort in mosques is essential because the mosque is a multi-functional space that is used for not only place for worship but also is but also a place for social-culture gatherings such as providing accommodation, welfare, education, and other social-cultural activities. Moreover, the mosque consumes more energy in the process of cooling the building when space is accommodated for functional activities. The authors in [9] agreed that thermal considerations are vital in most buildings involving people occupancy. However, the increasing trend of air conditioning used in Malaysian mosques is apparently increasing electricity consumptions in the daily mosque's operations. Nevertheless, the study relates to the energy consumption of urban mosque is insufficient even though many studies have been conducted on energy conservation in other types of buildings [9].

Indoor thermal comfort is investigated with respect to thermal performance, problems and possible preparations in mosques have acknowledged small care by researchers. The author in [10], conducted a study in the dry desert region in Riyadh, Saudi Arabia, in which he measured thermal comfort in a mosque at Friday prayers during the hot season and assessed visitor approval by Fanger’s model. The results indicate that visitor attending Friday prayer would prefer a cooler climate than the one recorded in the survey. Moreover, the author in [9] monitored energy use and thermal comfort in mosques in hot-humid climates of the eastern region of Saudi Arabia. The results show that the relatively high energy use does not aptitude thermal comfort in mosques and enhancing building envelopes with insulation and changing HVAC operation strategies can contribute to thermal comfort.

Air-conditioning in desert climate area is typically installed from the beginning of April to the end of October, which may have an incredible impact on the amount of electrical energy consumed to mechanically control the internal environment in mosques buildings. In addition, people in different climates feel comfortable at different indoor air temperatures. The indoor air temperature or thermostat temperature settings for all types of air-conditioned buildings and
mosque buildings in particular, are often considered based on the analytical model developed by Fanger [10]. Fanger stated that this model, where comfort sensation is predicted via the PMV has been adopted by the ISO 7730 as the standard approach for thermal comfort evaluation. The PMV value is a function of a set of environmental conditions that include: air temperature, mean radiant temperature, relative humidity, air velocity, and the individual-related variables of clothing insulation and rate of production of metabolic heat.

3. Methodology

The scope of the study for this project includes Arduino UNO which acts as a controller, a temperature sensor that will read the temperature in the mosque and sends the readings to the controller. The system is connected to the internet as proof-of-concept of IoT in order to provide remote control of temperature for the user.

3.1. Arduino Uno

Arduino Uno is used as a controller in this project. It will control the input and the output of the sensor and sends the signals to the fan when the temperature is being read. The speed of the fan is based on the temperature currently being read. Arduino Uno with 14 input/output is capable of handling the system using in-built software of Arduino.

3.2. Temperature Sensor DS1820

The sensor is used to detect temperature change in the surrounding. The features of the DS1820 is that it is pre-wired and waterproofed. The sensor has an operating temperature range of -55 to +125 °C, the accuracy of ±0.5 °, and covers the range of -10 to +85 °C. The sensor uses the Dallas 1-wire protocol that by definition requires only one data line and ground for communication with a central microprocessor. A 4.7k resistor is placed between the DATA and VCC to act as a pull-up. Moreover, The DS1820 measures temperature using an onboard proprietary temperature measurement technique.

3.3. Double H-bridge L293D

The L293d is used to control the two fans. L293d contains two half h bridge channels and a single fan can be controlled by each channel independently. The loads that can be controlled by each channel needs 0 - 36 volts and 600 mA of current. Two inputs and two output pins are provided by each channel. The fans are connected across the output pins of the channel. Control wires are connected to input pins. The function of the enable pin is to activate the channels.

3.4. ESP8266 Node MCU

The ESP8266 is a microcontroller designed by Espressif Systems and it is a self-contained Wi-Fi networking solution operating as a bridge from the existing microcontroller to Wi-Fi and is also capable of running self-contained applications. The module is used to connect to the Wi-Fi and it controls the fan through the web or smartphone.

The schematic circuit diagram of the fan speed control system is shown in Figure 1. In this circuit, the Arduino UNO is used to control the fan according to the temperature difference. The DS1820 role is to measure the changes in the temperature of the surrounding area.
4. Results and Observations
After implementing the circuit, the temperature sensor DS1820 is able to detect variations in the temperature of the environment. A minor delay was experienced as the temperature sensor took a short period to read the temperature of the surrounding. After the small delay, the fan started working. To alter the temperature of the environment, the temperature sensor is soaked into hot water and it was observed that the fan speed changes. It was observed that the higher the temperature, the higher the speed of the fan and vice-versa. The results of the experiment are shown in Figure 2 and summarized in Table 1.

![Schematic Diagram](image)

**Figure 1.** Schematic Diagram

![Result of Temperature Measured with Time](image)

**Figure 2.** The Result of Temperature Measured with Time

| Temperature | Fan State  |
|-------------|------------|
| 25.62       | OFF        |
| 28.37       | ON(30%)    |
| 32.13       | ON(60%)    |
| 36.13       | ON         |
| 27.68       | OFF        |

**Table 1.** The Temperature Measured and The State of The Fan.
The speed of the fan changes according to the room temperature and is controlled using Pulse Width Modulation (PWM) technique. The PWM signal is generated from NodeMCU for motor speed control and in the PWM signal output, the duty cycle of the signal is controlled. It can be observed that as the temperature increases, the duty cycle also increases. Hence, the fan speed increases. The duty cycle is shown in Table 2.

| Temperature | Duty Cycle | Fan Speed |
|-------------|------------|-----------|
| 25          | 0          | OFF       |
| 28          | 30%        | 30%       |
| 32          | 60%        | 60%       |
| 36          | 100%       | 100%      |

Another observation is that while the circuit is connected to WiFi at this IP address 172.20.10.13 provided by the NodeMCU, the fan can be controlled through the web server and smartphone by clicking the start/stop fan button.

### 4.1. Hardware Project Cost

Figure 3 shows the total cost for this project implementation which is just RM212.80. The list of components used is also presented in the figure below.

| NO | Description | Quantity | Material Cost Per Unit | Total |
|----|-------------|----------|------------------------|-------|
| 1  | Arduino UNO | 1        | RM66.00                | RM66.00 |
| 2  | ESP8266     | 1        | RM55.00                | RM55.00 |
| 3  | D1820       | 1        | RM59.00                | RM59.00 |
| 4  | LCD1602     | 1        | RM10.00                | RM10.00 |
| 5  | L298D       | 1        | RM2.80                 | RM2.80 |
| 6  | Brushless DC Fan | 2 | RM6.00 | RM12.00 |
| 7  | 9V Battery  | 1        | RM6.00                 | RM6.00 |
| 8  | Jumper Cable | 4 | RM3.60 | RM14.40 |
| 9  | Breadboard  | 1        | RM5.00                 | RM5.00 |
| 10 | Redstor 4.7K | 2 | RM0.95 | RM1.90 |
| 11 | Potentiometer | 1 | RM1.50 | RM1.50 |
|    | TOTAL       |          |                        | RM212.80 |

Figure 3. Hardware Cost Details

### 4.2. Cost Comparison with Smart Fan

There is an enormous growth of smart fans in the market nowadays. For the comparison, the smart ceiling fan designed and built by the company Big Ass Fans is chosen. The fan has SenseME technology which uses a combination of built-in sensors to autonomously control the fan's speed to maintain the perfect temperature. When someone enters a room, it will automatically turn on, and when the last person leaves, then it will automatically turn off. Table 3 shows the cost comparison for this project’s system prototype with the smart fan. From the comparison, the smart ceiling fan’s cost is higher than the proposed system and is not cost-efficient to be installed in every mosque.
Table 3. Price Comparison.

| System                  | Cost (US Dollar) | Cost (Malaysian Ringgit) |
|-------------------------|------------------|--------------------------|
| Smart Ceiling Fan       | 1045             | 4340.41                  |
| System Prototype        | 53.2             | 212.80                   |

5. Conclusion
The aim of this project is to design and construct a circuit that will automatically control the speed of a fan according to changes in the temperature of the surrounding. The circuit was constructed with a microcontroller, temperature sensor, and supporting components. The temperature and the fan speed are displayed on the LCD screen. The outcome of the project showed that the fan works perfectly well as the speed of the fan changes with the variations in temperature as well as can be automatically and remotely controlled via web browser and Apps.

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