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Energy Consumption of the Sensor Using Microcontroller In A Parking Space for Non-Fuzzy and Fuzzy

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Abstract—The use of sensors and microcontroller are among important technologies of recent times. Energy consumption of the sensor is an important consideration especially when designing and implementation of any network design such as in a parking space. Fuzzy Logic is one of the artificial intelligence techniques that represent fuzzy rule that can be combined with the Arduino microcontroller functions in order to calculate the energy consumption of the sensor. To calculate the energy consumption, formulas available in the Arduino's microcontroller function and formulas from established works of previous researchers are used. The objective in this report is to design the parking layout and develop a prototype by assembling Arduino and its components to be tested in the parking system, to define non-fuzzy and fuzzy rule in locating car location in the parking space to minimize the energy consumption and to calculate, compare and analyse usage of energy consumption of the sensors in the parking space before and after applying the fuzzy rule. The prototype system for the parking space is developed C programming language in the Arduino hardware and software. In the programming, the declaration and new definition of function and rules are created. The energy consumption, kilowatt per hour (kWh) is measured as the standards using INA219 sensor that can monitor the voltage, current, power and energy consumed. By applying the fuzzy rule compared to non-fuzzy rule in parking space, the result shows that the energy consumption has been reduced by 92.6%. To conclude, this paper can contribute of its benefits to optimize the energy consumption by applying fuzzy logic for a parking system.

Keywords- *fuzzy-rule; sensor, energy consumption, Arduino*

1. Introduction

Energy consumption of the sensor is an important consideration in designing and implementation of any network design. In this paper, parking space that is self-created has been chosen as case study. In order to evaluate energy consumption, functions and rules are created to generate the assigned parking lot.

The rules to evaluate energy consumption are based on Boolean Logic that is created without and with fuzzy-rule. Also, it can be used to derives conclusions as outputs from user inputs and the fuzzy reasoning process. The input will be number of cars enter and park into the parking space. For the function, every single sensor used in this paper calculates its voltage, current, energy consumed and operation time remaining

To represent the function and rules, an Arduino software IDE embedded with fuzzy logic library is used. As a result, the energy consumption can be evaluated by comparing the result of the energy consumption used for non-fuzzy and fuzzy rule. The analysis will be made using both of the results.

Paper organization consists of seven sections. The sections are introduction, literature review, experimental setup, methodology, design and implementation, result and analysis and conclusion and future works.

2. Literature reviews

2.1. Related Work

Due to the explosive growth of automobiles, parking space especially near to public area gradually becomes one of the most annoying things to car owners. In most cases, most of the users find the indoor parking spaces nearby are always full, and they have to drive around to look for any available parking space on the street. According to [1], with the continuous growth of automobiles, the situation becomes worse and worse. So the demand for street parking guidance service is expected to grow rapidly in the near future. Wireless sensors have lots of potential toward providing an ideal solution for street parking service, such as their low power, small size, and low cost based on [2].

2.2. Energy Consumption

The energy consumption in Wireless sensor is determined by three main components that are sensing, processing and transmission. Sensing energy consumption for sensor node is determined by the specific characteristics of the sensor, and its value is determined based on the device datasheet. In parking space, the wire-less devices which are battery-powered are used as the sensors to track the number of incoming car and out coming car in parking space. To calculate the energy consumption, the type of sensor used and energy efficient method can produce a better result depending on the situation that is described. In previous works, there are three equations, Equations 1 to 3, that are used to calculate the energy consumption. [3] The derived unit for energy is measured in kWh which is kilowatts per hour instead of Watt because the period of time for each predefined dataset in the experiment is one hour each.

Current, I = Voltage, V / Resistance, R (1)

Power, P = Voltage, V x Current, I (2)

Energy, E = Power, P x time, t (3)

2.3. Light-emitting Diode (LED)

A LED or light-emitting diode is a two-lead semiconductor light source. It emits light when activated based on Houghton Mifflin Company (2005). In parking system, LED is used to entrance, exit gate and all the parking lots. Green LEDs (parking lamp) are used in parking lots to determine the availability of the parking lot while white LEDs (indicator lamp and light source) are used as the source of light at the gates and the parking lot.

2.4. Light Dependent Resistor (LDR)

Based on [4], LDR is a type of sensor that works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity is increased when light is absorbed by the material. LDR decreases when light falls on them and increase if it is kept in dark. The ad-vantage of LDR is that it is cheap, smaller in size, consumed very small power and voltage for its operation. The disadvantage for this sensor is

that it is highly inaccurate and the response time is quite slow which is tens or hundreds of milliseconds.

2.5. INA219 Sensor

Based on [5] INA219 sensor is one of the best sensors in term of energy measurement and monitoring the problem. It is a small chip and very smart because it can handle high side current which is great for tracking battery life. This chip is used to measure the energy consumed by LEDs in kilowatt per hour (kWh).

2.6. Servomotor and Counter

There are two servomotors at the entrance and exit gate. The function of them is open and close the gate when the car enters or leaves the parking space. The counter is used to calculate the number of car enters and leaves in the parking space.

2.7. Fuzzy Rule

Fuzzy set theory can deal with the vagueness and uncertainty residing in the knowledge acquired by human beings or implicated in the numerical data. Fuzzy rule-based expert system contains fuzzy rule in its knowledge base and derives conclusions as outputs from the user inputs and the fuzzy reasoning process. [6]

In this paper, fuzzy rule is designed to differentiate the process in the parking system. This fuzzy rule creates a lot of inputs and outputs depending on the situation given. In term of energy consumption as the parameter, this rule is compared to non-fuzzy rule for the final result of the output.

3. Experimental setup

A parking layout is designed based on the list of sensors that are used, the arrangement of the sensors and how the sensors connects with each other in circuit of the parking design as shown in Figure 1.

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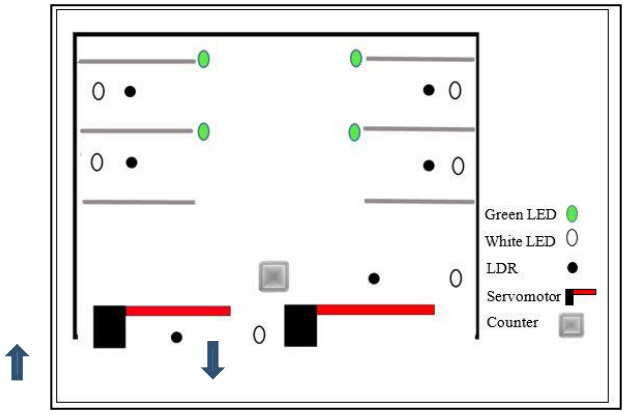

Figure 1. Overall Parking Design

Figure 1 shows the layout for the overall parking design. There are four parking lots available in the parking system. Each parking lot contains two type of LEDs which is green LED and white LED. Green LED is used as the Parking Lamp that as the indication to tell

the other users that the parking is occupied while white LED acts as the Indicator Lamp that as the guidance where the user or driver parks the car that is assigned the parking lot. Also, there are four LDRs installed at each of the parking lot. The LDRs are the input that reacts with the light intensity that changes the output of Indicator and Parking Lamp.

At the entrance and exit gate, there are two LDRs, two servomotors and one counter near the gates. The LDRs are used to operate the servomotor at both of the gates. If the car blocked the LDR sensor, it gives the signal to Arduino and allows the current to flow from the Arduino to the servomotor. Hence, the servomotor is operated except if the parking is full. The counter is used to count the number of the car entering and leaving the parking space.

4. Methodology

There are five steps that are used to create the parking system with the completed functions and rules to produce the results.

4.1. Identify the Input and Output

Once the parking layout has been completely designed, identify all the input and the output based on the parking design itself. The input that is used in this paper is LDRs and the output is the display, servomotor and LEDs.

4.2. Define Boolean Logic of the Input and Output

Create the table to define Boolean Logic to identify the relationship between the input and output in the circuit. With Boolean Logic, every single sensor can be programmable using this logic. There will be two types of Boolean Logic that will be defined which is non-fuzzy and with fuzzy-rule.

4.3. Data Collection and Evaluation of Energy Consumption

There are three pre-defined in datasets of 10 cars in parking system per hour for each dataset with random time duration in the parking lot. For example, in Table 1 is the dataset of energy consumed by parking lamp for non-fuzzy.

Table 1. Dataset of Energy Consumed by Parking Lamp for non-fuzzy

No. of Car	Arrival Time	Depart Time	Time Duration (min)	Parking Lot
1	9.00	9.15	15	P1
2	9.10	9.28	18	P4
3	9.20	9.48	28	P3
4	9.25	9.39	14	P2
5	9.30	9.38	8	P1
6	9.35	10.00	25	P4
7	9.40	10.00	20	P2
8	9.45	10.00	15	P1
9	9.50	10.00	10	P3
10	9.55	Null	Null	Full

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4.4. Result for Non-Fuzzy and Fuzzy Rule

For the fuzzy-rule, the programming method used is based on Boolean Logic that is related with fuzzy. The different is that, it consists more than one declaration of variables which is the input to control whether one or more outputs.

4.5. Compare Both Result and Make Analysis

After the result without and with fuzzy rule have been achieved, the comparison will be made on both of them. The analysis will be conducted to compare the results which is the energy consumed by the Arduino boards (sensors) without and with the fuzzy rule.

5. Design and Implementation

5.1. Parking System Operation

Each component will give the response to certain inputs by giving its outputs and the outputs will be other input sources of other component. These inputs and outputs will give a circulation to the system to be more responsive and do the job consequently and stable.

5.2. Design of Prototype

The parking space is designed using the LDR sensors, two types of LEDs which is Parking Lamp (green LED) and Indicator Lamp (white LED), servomotors for the gate and a counter to count the number of car enters and leaves the parking space. Fig 2 below depicts example of the operation of the parking system for non-fuzzy.

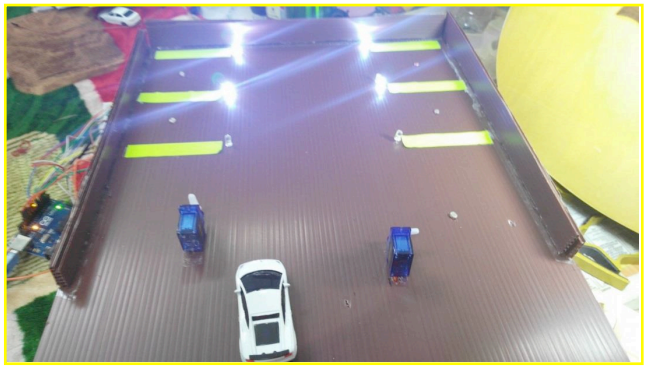

Figure 2. Operation of the parking system without fuzzy rule before parking

5.3. Input, Output and Counter

When designing the parking system, it is essential to identify the input and output that are placed in the parking space. Input is one of the important variable that is measured to determine what the output is. There are six inputs that have identified when conducting this experiment. These inputs are represented by the sensor called LDRs. In this parking space, they are placed at the entrance gate, exit gate and at the parking lot. For the output, there are two servomotors, four green LEDs (parking lamp) and four white LEDs (indicator lamp). For each parking lot, one green LED and one white LED are placed. The counter which is 7 segment display, counts the number of car enters and leaves the parking space.

5.4. Boolean Logic for Non-Fuzzy

For non-fuzzy rule, there is no rule applied in this parking system. The user can leisurely enter the parking space and park the car anywhere that the user wants to. If the parking is full, the user cannot enter into the parking space. As for the parking lamp and indicator lamp. All the indicator lamps are on when the parking lot is empty and once the user parked the car in the parking lot, indicator lamp turns off and parking lamp turns on.

5.5. Boolean Logic for Fuzzy Rule

In Fuzzy rule, queue method is applied in the parking system which is based on priority of the parking lot. The parking lots are labelled as P1, P2, P3 and P4. The priority is based on the first parking lot and so on. When a user enters the parking space, Only P1 turns on the indicator lamp. Once the user parked in P1, indicator lamp turns off and parking lamp turns on. Another example is when P1 and P4 are occupied, the next car enters the parking space and there are two parking lots available which is P2 and P3. P2 is chosen based on the priority.

6. Result and Analysis

To measure the energy consumption, INA219 sensor is needed because it can monitor and measure the energy consumed. The results are based on energy consumed by the Indicator lamps for all the parking lots. The result of energy consumed is shown in Figure 3 to 5 as the first, second and third dataset.

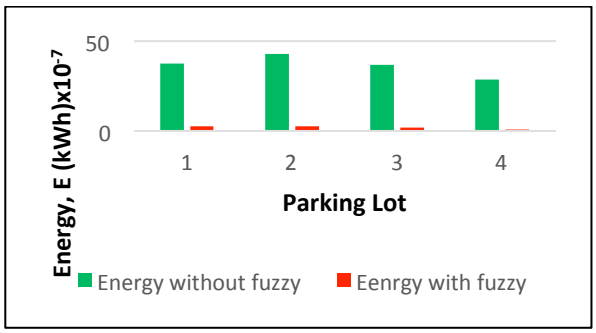

Figure 3. Result for the first dataset

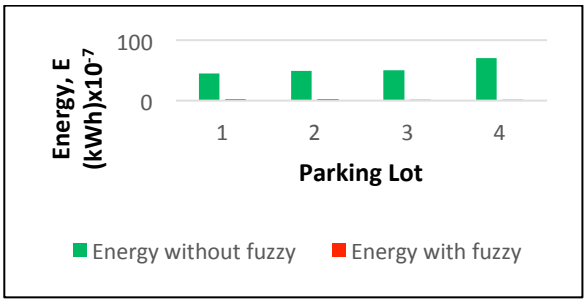

Figure 4. Result for the second dataset

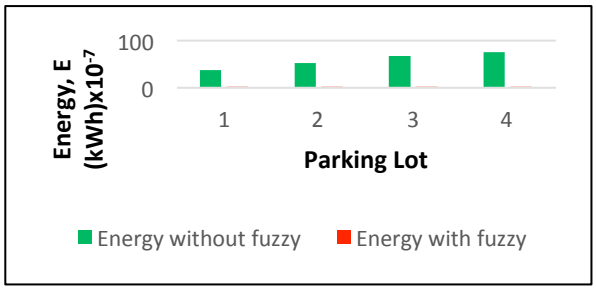

Figure 5. Result for the third dataset

Table 2. Total Value of Energy Consumption jor Non-Fuzzy and Fuzzy in Three Datasets

No. of Datasets	Energy Consumption for Non-Fuzzy Rule (kWh)x10^{-7}	Energy Consumption for Fuzzy Rule (kWh)x10^{-7}
1	145.8	7.6
2	214.8	7.6
3	232.9	7.6

As in Figure 3 to 5, the difference of energy consumption for indicator lamps are in a huge gap to each other. This is how the fuzzy rule plays an important role because it made a big change to the indicator lamps operation. Fuzzy rule contributed a lot especially to the management to maintain all the sensors in the parking lot which can save a lot of money, time and energy. For the calculation, in Table 2 refers to the total value of energy consumption for non-fuzzy and the total result of energy consumption for fuzzy rule in three datasets.

Average energy for non-fuzzy = (145.8 + 214.8 + 232.9) / 3

= 197.83 kWh

Average energy for fuzzy = (7.6+7.6+7.6) / 3

= 7.6 kWh

Total Energy used = 197.83 + 7.6

= 205.43 kWh

Energy reduction = 197.83 – 7.6

= 190.23 kWh

Percentage, % for energy reduction = 190.23 / 205.43

= 92.6%

The average value of energy for non-fuzzy and fuzzy rule in all three datasets is 197.83 kWh and 7.6 kWh. In term of energy optimization, the percentage by using fuzzy rule to non-fuzzy is 92.6% which means that fuzzy rule saves about 92.6% energy compared to non-fuzzy.

7. Conclusion and Future Works

In future, we are planning to add more advanced sensors that able to detects the incoming target in more efficient ways so that the sensors will be able to collect the data more accurate and systematic.

To conclude, with the help of fuzzy rule, it creates the algorithm in more organized ways and complex. In term of mechanism, the operation of each sensor is very difference compared to the one that use non-fuzzy rule. As the operation of the sensors varies between non-fuzzy and fuzzy, the energy consumed should produce a different result.

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