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A Novel Faulty Light Detection System using RFID

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Abstract: A reliable method for identifying faulty lights in big areas is indispensable and a challenging task. In this study, we propose a fault light detection system to overcome current solution's drawbacks, especially in indoor facilities. The Radio Frequency Identification (RFID) is utilized for the automatic detection of light faults. The proposed system is an effective method for monitoring a large area lightning system from remote area without visiting the location. Comparing to the indoor systems, the implementation and testing results indicate and improvement in the reliability while reducing the cost of the proposed system.

Key words: Fault detection, RFID, light sensor, indoor systems, drawbacks, reliability

INTRODUCTION

Smart city and smart home are emerging concepts that use different types of electronic data collection sensors to supply information used to efficiently manage assets and resources (Choi *et al.* 2018; Gubbia *et al.*, 2013). Hence, there is a strong demand to intelligently manage and control street light infrastructures. The indoor and outdoor light control systems play an important role in not only the reduction of energy consumption of the lighting without impeding comfort goals but also in safety and security purposes (Downie *et al.* 2017; Iyer, 2018).

One main challenge in this area is the difficulty to detect defects in lighting systems in public places with large areas such as airports, hospitals and streets (Chen and Chou, 2015; Chien, 2007; Cho *et al.*, 2015; Green *et al.*, 2017). Also, the need for a skilled person to inspect every light for the possibility of a defect waste time and efforts in addition to the possibility of missing near-faulty lights due to human error and eye fatigue.

Therefore, there is a need for an automatic fault light detection system. Unfixed faulty lights increase darkness which negatively affects human's safety and/or productivity. Different solutions were proposed to detect light faults. In this study, the proposed previous solutions are analysed and evaluated. Based on the investigated solutions, a fault light detection system is proposed to overcome current solution drawbacks specially in indoor facilities. In this study, the Radio Frequency Identification (RFID) technology is utilized for the automatic monitoring and detection of light faults. In addition to the usability of these systems in outdoor, we concentrate in this study to design the system to fit also indoor system's demand. This research is an extended research of Naser and Abuamara (2018) where the preliminary prototype of the designed system is detailed. In the extended version, the implementation and testing and the result sections are explored.

MATERIALS AND METHODS

Current solutions: The first use of Radio-Frequency Identification (RFID) system was used to Identity Friend or Foe (IFF) during World War 2 (Domdouzis *et al.*, 2007). Since that date, different systems were proposed for human identification, warehouse management and toll system to list a few (Naser *et al.*, 2009; Iyer, 2018).

Different systems were proposed to detect and identify light faults. Rajput *et al.* an intelligent street lighting system using GSM was designed to resolve the faulty street light issue. The main purpose of this device was to track faulty lamps and send data to the control centre. The used system required a microchip to be installed on the pole lights. The used chips consisted of a microcontroller along with different sensors such as CO_2 sensor, smoke sensor, light intensity sensor, noise sensor and a GSM module for wireless data transmission and reception between microchip and Primary Concentrator

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(PC). The PC transmitted the controlling action to the microchip. The used system had some weaknesses such as the need to place a microchip in outdoor which affected the lifespan of the microchip due to environmental issues. Also, the high construction cost and required material made the system uneconomical. These drawbacks decreased system's reliability and increased maintenance and installation costs.

In another research, a smart monitoring fuzzy-based fault detection system for malfunction traffic light operation was proposed (Naser and Abuamara, 2018). The main purpose was to solve the issue in a rural area or small city that did not have a traffic monitoring controller. The used system identified three types of fault which are amount of LED brightness, electrical outage and physical defect. The system composed a message to be sent to a control room. The used system had same issues the GSM-based system by Rajput *et al*. had. Another system, based on sequence-fuzzy controller was used to check the LED brightness level (Soh *et al*., 2013). The idea is that for each sequence of traffic light junction and for each pole, only one of the LEDs will be activated while the other LEDs will not be activated. If the LED did not show the correct sequence (Green, orange, red), the LED is diagnosed as faulty and the system send the notification to a control centre to make an action. The used solution was limited to traffic lights only and cannot be implemented in other fault light detection systems.

Saleem *et al*. (2015) a street light monitoring and control system was designed to minimize the time that a workman spends in searching and locating the faulty light. The light sensors were placed in all street light's circuit to switch on and off automatically. Once the lights are switched on, the sensors placed at every light pole were responsible to send light's status to a centralized system using a GSM module attached with the circuit. The proposed system was efficient in the outdoor fault light detection. However, the system was not economically feasible for indoor big facilities with huge number of light bulbs. Also, not all light bulbs come with circuits to make the solution feasible.

Tseng and Hsieh *et al*. (2016) a G3-PLC-based solution for intelligent street lamp monitoring and energy management was proposed. The main purpose of this is off or missing a wire, since, it took a long time to solve system was to detect street lamp issues such as the light it manually. The proposed system had weather resistance, 24 h automatic monitoring, wide monitoring range and automatic routing capability to detect every lamp's status such as power consumption, on-off state and temperature. It had the features of street lamp energy-saving control and multiple alarm modes for users to choose. The management system comprised of street lamps, street lamp monitoring server and street lamp monitoring client-side. If a street lamp had an open maintenance hole, electricity leak or did not light, a warning was sent via. power lines to the G3-PLC host, concentrator and the server via. the GPRS or an SMS short message. The used system was not economically feasible due to the use of GPRS and SMS messaging. On the other hand, this system cannot be implemented in indoor places due to the limited ability of this technique to identify faulty lights to a small distance accuracy.

Sumathi *et al*. (2013) an arm-based street lighting system with fault detection was designed to identify street lamps status where a GSM module was used to send messages. Each street lamp was monitored using a fault detection circuit. In case of any faulty lamp, the circuit sends the information to the controller which in turn notifies the corresponding maintenance department using the GSM module. A light dependent resistor was attached close to the street lights to detect any bulb faulty condition. The Light Dependent Resistor (LDR) offered a high resistance value thereby making the circuit open. An arm processor checks for this condition only when the corresponding street light is switched on. When this condition is triggered, the arm processor sends a message to the control room using the GSM modem connected to the processor and thereby had a good management system. One of the main weaknesses of this system is its cost.

In summary, all the previously discussed proposed systems did not target indoor areas. Also, they require to replace the current used lighting system with the proposed system which takes time and increase cost and thus, hinder the adoption of that system. Table 1 shows a comparison between different fault light detection systems. The comparison is done based on reliability, cost, maintenance cost, lifespan and indoor suitability.

Table 1: Comparison between different fault light detection systems

Used system	Reliability	Cost	Maintenance cost	Lifespan	Indoor suitability
Rajput *et al*. (2013)	Low	High	High	Low	Low
Soh *et al*. (2013)	Moderate	High	High	High	Not applicable
Saleem *et al*. (2015)	Moderate	Low	Low	Low	Low
Tseng and Hsieh *et al*. (2016)	Moderate	High	Low	Moderate	Low
Sumathi *et al*. (2013)	Moderate	High	Low	Moderate	Low

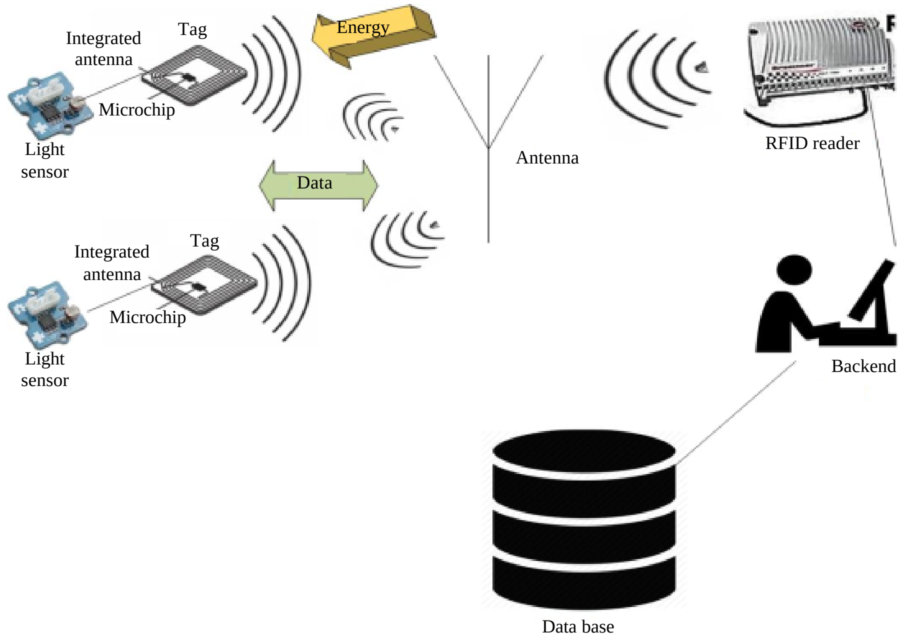

Fig. 1: Proposed light fault detection system

RFID-based fault light detection system: The Radio Frequency Identification (RFID) is used for the automatic identification of objects carrying tags based on radio-frequency electromagnetic waves transmitted to a receiver (reader). The proposed system focuses on the indoor fault light detection. First, the proposed system architecture is discussed. Second, the data flow of system components is explored. Third, the activation circuit manufacturing is discussed. Finally, the light wiring implementation is shown.

Proposed system architecture: The proposed fault light detection system includes hardware and software components that interact with each other to detect the faulty lights as shown in Fig. 1.

In summary when the lights are inactive, the light sensor activates the RFID tag to communicate with the reader through sending ID of the faulty light. The RFID tag uses the Tag Talk First (TTF) protocol to alert the RFID reader that the light is not functioning. The reader sends alerts to the backend system which locates the faulty light based on the database. Finally, a report is sent to the technician to fix the faulty lights. Practically, the fault detection process will use the RFID to make the detection process of any faulty light easier and faster. The used system consists of hardware and software components. The used hardware components are Arduino Uno R3 (Badamasi, 2014) display LCD 16×2, I2C, mini photocell, 10 mm LEDs, RFID tag and reader. The I2C is used to transfer data, bit by bit, along a single wire. On the other hand, the used software components are Arduino 1.8.4 and fritzing and multisim. The detection system works as follows. If a light goes off or blinking, the light sensor measures the intensity of the light and sends a signal to the Arduino Uno processor. Based on the measured voltage values, the tag will be activated and send a signal to the RFID reader. At the end, RFID tag number will be sent to the central server. Figure 2 describes the flow of data signalling from the light sensor to the server.

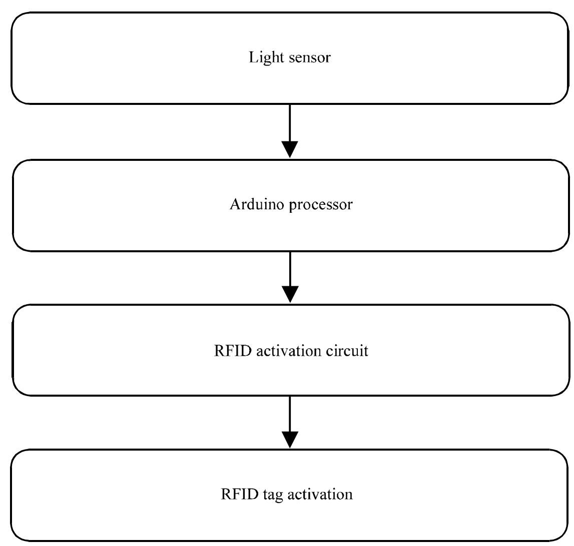

Fig. 2: RFID activation procedure

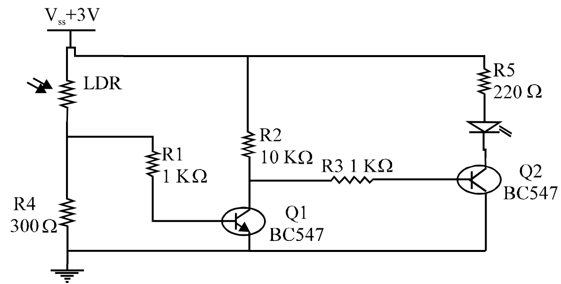

Fig. 3: The RFID activation circuit

Data flow model: In order to understand the interaction between the detection system components, we describe here, the data flow control among these components. First, the system's hardware connection is described as follows:

LED: Represents the source of light that will be checked in the environment.

Photocell: A light dependent resistor used to sense the intensity of the light (LED). This component is critical to system, since, it helps in minimizing the noise caused by other lights in the area, especially in indoor area.

Tag module: A tag activation circuit that allows the LDR resistance and the transistors to switch on/off the active tag, depending on the light situation and the output of the Arduino circuit.

Arduino circuit: The software part of the design. It has the program that receives information from scanner and outputs the tag to be sent to the RFID reader. This component has the necessary circuit that help in checking the light low intensity.

RFID reader: Represents the active tag scanner through antenna. It is a wide area reader that reads the tag of any faulty light when it is activated.

Database: It is hosted in a server to build historical data for all lights in the system. This should help in studying the environment and understanding the reasons of the damage in the lights.

Activation circuit manufacturing: The circuit design as shown in Fig. 3 has two transistors and an LDR. When a light fall on the LDR its resistance decreases and the first (Q2) gets high base voltage and turns ON. This allows the transistor (Q1) is off which makes the second transistor current to flow through the tag and activate it. When the LDR resistance is high, the second transistor (Q2) is OFF and the first transistor (Q1) gets low voltage which will not allow the current to flow through the tag. Table 2 shows the RFID tag activation circuit using the LDR light intensity. After designing the activation circuit using the express PCB, it is printed on a clear laminated sheet to mark the areas that will become copper on the circuit board. The circuit is marked on a copper-clad board that is sensitive to UV light. Next, a development tank containing sodium hydroxide is used to develop photo-resist coat on the board that removes the UV sensitive layer. Then, the etching tank is used to etch off the copper, except the copper that is covered by photo-resists to form the circuit lines. Once the board is printed, etched and cleaned, the driller is used to drill holes for component's pins. Finally, each component is soldered in its planned place while the resistors and transistors are soldered directly on the board. However, the LDR and tag are connected to the board through wires.

Lights wiring implementation: The LEDs are connected in parallel with the 5-V power supply and a switch. Each LED is connected in series with 560 Ω resistor. The PCB board is designed to connect the circuit, iron solder is used to connect the resistors on the board and the wires are linked to LEDs and a switch.

Faulty light system analysis: Several antennae are connected to a single reader to gather data from the RFID tags which makes the proposed faulty light detection system economically feasible. This system can be implemented in indoor areas such as warehouses, airports, hospitals, stadiums, etc. Since, the RFID tag is placed indoor, the impact from environmental factors is minimized which should increase the lifespan of the used system. The system also does not require changing the light bulb or the lighting system, since, the RFID tag and light sensor can be fixed inside the light case as shown in the light case samples in Table 3. Therefore, this technique reduces the maintenance costs. Finally, the high durability of RFID tags reduces the required maintenance cost and efforts. The proposed system showed better results than similar detection systems in terms of reliability, cost, maintenance, lifespan and indoor suitability as shown in Table 4.

Table 2: The RFID tag activation circuit using LDR light intensity

LDR light intensity	LDR resistance	Q1 transistor status	Q2 transistor status	RFID tag status
High	Low	OFF	ON	Activated
Low	High	ON	OFF	Not activated

Table 3: Sample light case components for each light bulb including light sensor and RFID tag/antennae

Light case samples	Light bulb	LDR light sensor	RFID tag/antennae
1	LB 1	1	Tag ID 1
2	LB 2	2	Tag ID 2
3	LB 3	3	Tag ID 3
4	LB 4	4	Tag ID 4

Table 4: Comparison between proposed and similar fault light detection systems

	Reliability	Cost	Maintenance cost	Lifespan	Indoor suitability
Rajput *et al.* (2013)	Low	High	High	Low	Low
Soh *et al.* (2013)	Moderate	High	High	High	Not applicable
Saleem *et al.* (2015)	Moderate	Low	Low	Low	Low
Tseng and Hsieh *et al.* (2016)	Moderate	High	Low	Moderate	Low
Sumathi *et al.* (2013)	High	High	Low	Moderate	Low
RFID-based fault light detection system	High	Low	Low	High	High

Table 5: Status of events from switch control to RFID reader display for light case sample 1

Control switches status	LDR1 light sensor intensity	Light bulb LB1 status	Light bulb LB1 operation	RFID tag/antennae activation status	RFID reader or scanner reading	LCD and Light Bulb Database server output
Pressed	High	ON	Working okay	Not activated	-	-
Not pressed	Low	OFF	Faulty	Activated	Tag ID 1	Light bulb LB1 faulty

RESULTS AND DISCUSSION

The simulation part is done using fritzing to verify the feasibility of the idea. Moreover, a hardware prototype is developed to further establish the practical significance of the concept. The experimental procedure includes several steps. The light circuit and activation circuit are drawn using the PCB Software. Then, the final module of the system is designed.

An important step of the experimentation phase includes distributing the module in the area and deciding where to place the detection system and its components in suitable places. After that, the circuit on breadboard is printed using etch tank technique. Later, the drilling and soldering of the components on the board is done. Finally, to finish the system, the LEDs are connected in parallel, two switches for the faulty light are installed and then the power supply is connected using a 5 V adapter. The experimental results show that the faulty light will activate the tag and then the scanner reads the ID number of RFID tag and the data is sent to the database server. The sequence of events is shown in Table 5.

Two different tests are conducted to validate the proposed faulty light detection system. In the first test, the two switches inside the faulty light are used to control the experiment. When one of the switches is pressed, the light turns off. The LDR measures the light intensity. Then, the switch is turned off causing the intensity to go down. After that, the activation circuit start working where the tag transmits the signal to the scanner which reads the light number and display it on the LCD using the Arduino Uno. The active RFID scanner can read from a long distance in the range of 25 m. One of the challenges faced in this project is to test the active scanner in reading the active tag.

In the second test, the Wieg and 26 scanner wires are connected. Then, an application is developed in Arduino Uno Software to read the tag and display it on the serial monitor. Once one or both switches are pressed, the light turns off. Then, the passive RFID tags that are attached to the tracker sends a signal to the FRID scanner. The developed Arduino Uno application can receive the detected data transmitted by the RFID scanner from a 60 m distance and displays it on the LCD display unit attached to the control centre.

CONCLUSION

The current fault light detection systems are investigated in this study. The available systems did not target indoor areas, require replacing the current used lighting system with the proposed system and require time and high cost to implement. An RFID-based fault light detection system was proposed in this study. The proposed system showed better results than available systems in terms of reliability, cost, maintenance cost, lifespan and indoor suitability. Future research should investigate two main issues. First, security issues of the proposed system such as immunity against eavesdropping, replay, man-in-the-middle, denial of service and RFID counterfeiting. Second, the cost issues and how we can reduce the cost of the deployment in order to make it more sufficient and sustainable.

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