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Improving the Performance of IoT Bidirectional Visitor Counter (A Novel Practical Framework)

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Abstract

Internet of Things (IoT) has sustained a great opportunity to introduce powerful industrial IoT (IIoT). IIoT applications are taking advantage of the growth in radio-frequency identification (RFID) everywhere. Various graduation projects were published, yet most of them could not be practically applied due to their limitations. One of these projects was "Personal Visitor Counter (PVC)." This paper introduces practical solutions to the most critical limitations. The evolution of PVC is also demonstrated. Moreover, IoT networks may use many people in a place as control information. The collected information, processed with others, can help IoT-automatic controlled systems use features of the environment in which they are deployed. Consequently, the integration of captured data provides the development of various applications, such as regulators of air conditioning appliances, and privacy and security leaks, in addition to helping people manage their work environment. One of these applications is minimizing electric power wastage. The main objective of this research is to develop a framework that rectifies visitor counter-system problems. The proposed framework was implemented and tested for nine months to rationalize the usage of electric power. The experiments determined the best practices for places to put sensors. A local patent was registered for PVC to start the production process.

Keywords: IoT, person visitor counter, electric power wastage, photoelectric switch, relay

1. Introduction

Iot is both a podium and a phenomenon that allows objects to manipulate information, communicate data, analyze context logically in the service of individuals, associations, and businesses. Big data with different formats and content have to be efficiently, quickly, and rationally retrieved through smart systems, techniques, frameworks, and tools. The new framework is enabled by the progress of technologies, including the internet, wireless communication, cloud computing, sensors, big data analytics, and deep learning algorithms.

Over the last two decades, IoT has been in a sustained evolution. Some of the most prestigious management-consulting firms, such as Gartner, McKinsey analysis, and ABI Research, had forecasted that IoT appliances would grow from about 5 billion devices in 2014 to around 20 billion by 2020. In terms of hardware spending, consumer applications amounted to $1534 billion by 2020, while the use of connected things in the enterprise reached $1477 billion in 2020. As a result, the US National Intelligence Council included IoT into the list of six "Disruptive Civil Technologies" with potential impacts on US national power [1].

Kao stated that the information delivered by IoT devices have an intuitive property of imperfection, and that its quality is highly impacted by the way it is acquired. In fact, this information may not even be correct. Thus, an inherent inaccuracy (e.g., meters for GPS positions or correct places) is characteristic of most sensors. Furthermore, each technology has its own limitations and specifications, which creates some technical restrictions during the development of an IoT device [2]. However, a wide range of industrial IoT applications has been developed and deployed in recent years. To understand the development of IIoT, Sheelwant *et al.* introduced "Internet of Things in Industries: A Survey," systematically summarizing the latest IoT in industries. According to their definition of IoT, "IoT can be considered as a global network infrastructure composed of many connected devices that rely on sensory, communication, networking, and information processing technologies." Figure 1 shows technologies corresponding to IoT [3].

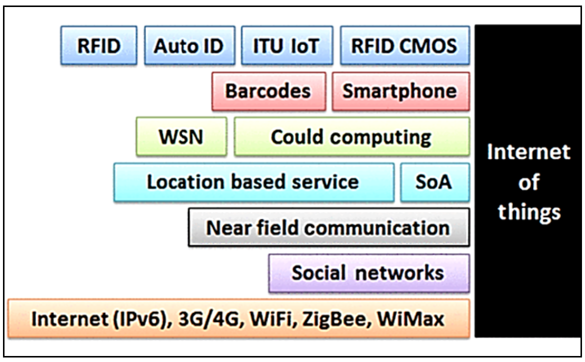

Fig 1: Technologies corresponding to IoT.

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Visitor counter-explained in the next section-is used to automatically reduce wastage of electricity, which affects the environment directly and indirectly. It reduces the bills of electric power usage. It also exhibits an effect on non-renewable resources, which are sweeping out from the earth for the need of human being. In addition, the unnecessary usage of electrical appliances increases earth's surface temperature. This is part of Green Electric Power utilization. To control electricity wastage, an automatic power control apparatus is monitored by the number of persons count in a place, and accordingly switches on the electrical appliance and light. The process of counting the number of persons entering and leaving is conducted via a sensor circuit. The limitations of the published circuits are posed as a result of being low range circuits and cannot be practically implemented. With the regular change in the count value, and after many uses, the output may deliver wrong results [4].

This paper introduces a practical application of PVC to rationalize the consumption of electric power, particularly for official government offices. Following this introduction, Section II summarizes the literature review and background, Section III demonstrates the proposed framework, Section IV discusses the experiment evaluation, and finally Section V presents conclusions and future work.

2. Literature Review and Background

Recently, Industrial Automation and Control Systems (IACS) were differentiated from conventional digital networks such as enterprise ICT environments. As connectivity was required, a zoned architecture was tailored with firewalls and/or secured zones, for the purpose of protecting the components of the central control system. The adoption and deployment of 'Internet of Things' (IoT) technologies have led to architectural changes to IACS, including greater connectivity to industrial systems. Many research papers reviewed the definition of IIoT, and its relationship to concepts such as cyber-physical systems, and Industry 4.0. [5].

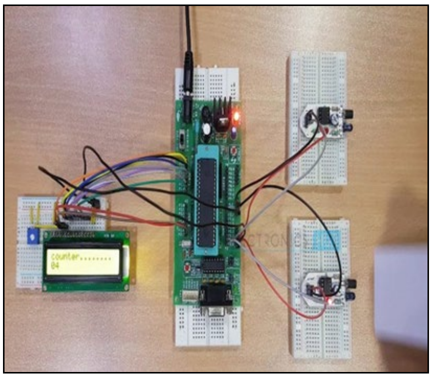

Fig 2: Bidirectional Visitor Counter deployed by 8051 microcontrollers

Visitor counter is an applied IIoT that is simply a numerator of the number of visitors entering or exiting places, such as workplaces, shopping centers, sports venues, etc. Enumerating visitors helps to improve the efficiency and effectiveness of employees, floor areas, and sales potential of an institution. Visitor counter is not limited to a single entry/exit point of a place; it has a wide range of applications that provide information to management on the volume and flow of people throughout the many doors to a single place. A primary way for counting visitors involves hiring human auditors to stand and manually tally the number of visitors who enters/exits a location. Figure 2 shows a published Bidirectional Visitor Counter deployed by 8051 micro controllers [4].

Infrared (IR) sensing was used in the project's circuit. IR Sensors are devices that operate as a Transmitter and Receiver, respectively using an Infrared Light Source and a Photo Detector, such as a Photo Diode or a Photo Transistor. The IR Transmitter in the present project was an IR LED, while the IR Receiver was a Photo Diode. Two infrared sensor circuits were used, each consisting of an infrared sensor. The output of each sensor feeds the microcontroller. In a normal case, IR light from the LED does not affect the Photo Diode as it is a Reflective type IR Sensor. The output from the sensor would be a logic LOW signal in this situation. In case of any interruption due to any person crossing the path, the Photo Diode would start receiving the IR Light, and begin conducting. As a consequence, the sensor's output would be a logic HIGH signal. The microcontroller detects the transition from low to high, for each sensor pair. Accordingly, the count is increased or decreased.

Electric Power Consumption (EPC) Bills have become a financial burden to citizens and institutions. In Egypt, this problem has been causing concern for all citizens. The increase in EPC is due to carelessness or failing to switch off lights. Many trials and projects have been undertaken to aid in the reduction of EPC. The Internet of Things (IoT) is a set of connected devices that can sense, identify, process, communicate, and network [3]. The Electronic Hub website [Hub 2018] features a project titled "Bidirectional Visitor Counter using 8051 Microcontroller." Carvalho *et al.* tested their IoT individual counter implementation in two separate technologies [2]. Chander's graduation project is "Bidirectional Visitor Counter" [6]. When using the counter in real life, a lot of limitations emerged. One of these limitations is the detection range, which was 5 cm in the mentioned project, hence not a practical application. The 5 Ampere relay would be overloaded and made working if their circuit was used to rationalize the use of electric power.

Table 1 presents the result of the accuracy evaluation, as Carvalho *et al.* ran some controlled tests (scenarios) [2]. In scenarios where only one person moves in front of the system at a set time interval, the devices produced results that were close to those predicted, suggesting that they can be used in real-world situations. The inactivation time ranges for motion and ultrasonic technologies were 2,5 seconds and 500 milliseconds, respectively [2].

Table 1: Accuracy of Carvalho *et al.*'s scenarios implementation

Scenario	Accuracy Result: Ultrasonic	Accuracy Result: Motion
1	90%	81%
2	0%	0%
3	0%	0%
4	87%	50.3%
5	63.2%	49.8%
6	58.7%	12.4%
7	0%	0%

Yadav *et al.* presented "A Look at Smart Home Automation Using the Internet of Things," discussing some applied systems, such as Governing of Light, Power Window, Smart Terrace Garden, and Child Back to Home. They made a comparative study, and concluded with a strong statement recognizing that their current scheme had a number of flaws, such as energy consumption, water waste, child safety, etc.

Assumed scenarios were to be considered to get better results [7].

Archana *et al*. presented "Bidirectional Visitor Counter for Smart Power Management," introducing their project to manage the electric power for fans and light and using the same implementation as in Xu's project mentioned above. They, however, added a temperature sensor to control the fans, but did not resolve any of the limitations in Xu's Project [8].

Most of the published systems are theoretical applications with limited detection range. None of the published projects were practically applied. Figure 2 shows one of the published projects [4]. The detection range for this type of sensor was 5 cm [9]. This range was not practical, which was the first problem to be tackled. The second problem was the distance separating between the two sensors.

3. Proposed Framework

The gap found in previous frameworks could be briefly identified in two main points. First, the range of the motion sensors was very small and non-practical (less than 5 cm). Second, the error due to the interference of the motion sensors was very high. The proposed practical framework solved these issues.

Figure 3 demonstrates the proposed framework. There are two added values in this framework. The first is the sensing range of the PIR sensors. For the present study, Photoelectric Switch was used, working from 2 meters to 3.5 meters, as shown in Figure 3, whereas the previously published was 5 cm. The second added value was using a 60 Ampere relay to protect the circuit.

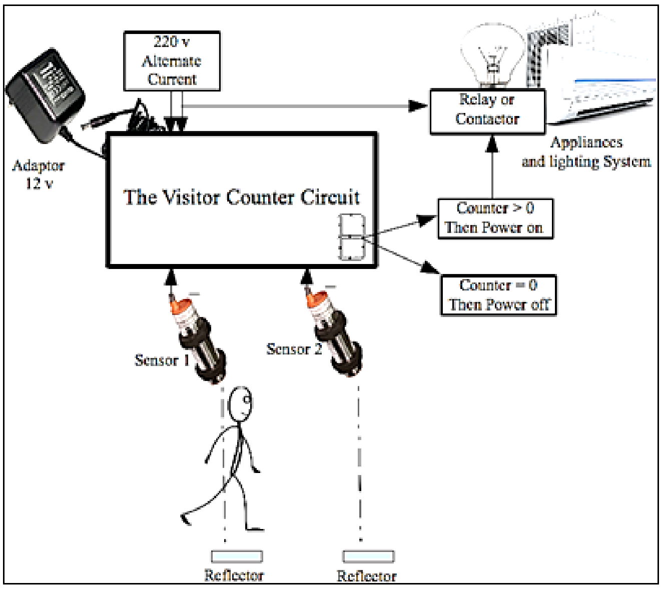

Fig 3: Proposed framework.

Figure 4 shows the detailed new circuit diagram for the proposed framework. A new added value was created after the practical application of the proposed framework. Some of the offices had two doors. Thus, a new challenge was revealed regarding the way to count visitors coming in and out of that place. Consequently, the setting of the sensors represented a real challenge. The main problem was caused by the interference of the rays that sent and received, when reflected from both sensors. Many experiments were tested to find the optimum distance to set sensors. In case of slide doors, sensors would be set one before the door, and another after the door. In case of hinged doors, one sensor would be placed in the fixing frame (front the door), and the other sensor would be set before the last point reached by door rotation.

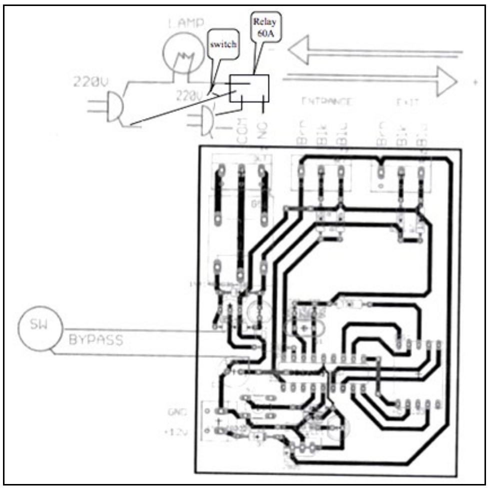

Fig 4: Detailed Circuit Diagram for Proposed Framework

Figure 5 shows a new circuit, taking into consideration that the place under study had two doors. This framework was assembled and tested in the author's office, few weeks ago. The system was stable, and the interference of the Photoelectric Switch ray was resolved by separating the sensors by one meter.

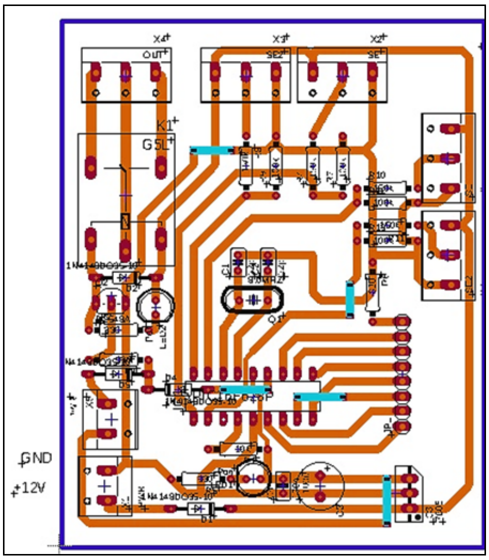

Fig 5: Two Doors Circuit Automatic Controller

4. Experiment Results

Experiments and results are shown in Table 2.

Table 2: Experiments and their results

Serial	Distance Between Sensors in CM	Results
1	0	Failure
2	35 CM	Failure
3	85 CM	98%

The first two experiments failed because of the interference of the sent beams and the reflected beams. The 2% error was due to the passing speed of the person, and the sensitivity of the sensors.

5. Proposed Framework Evaluation

The experiment of the proposed framework was tested after being assembled and installed in the author's office since Dec.

2018. Daily observations were closely done. The distance between the two Photoelectric Switches was adjusted after many trails reaching one meter, which prevented the interference of the rays of each Photoelectric Switch. Moreover, this enabled handling the body size of each visitor, as it caused the recognition. Different types of sensors were tried. Ultimately, the most suitable types were determined, namely E3JK-R4M2 photoelectric switch shown in Figure 6, and Photoelectric Switch Sensor 12-24VDC, with detection distance up to 2m (Figure 7).

Fig 6: A E3JK-R4M1 Photoelectric Sensor Switch

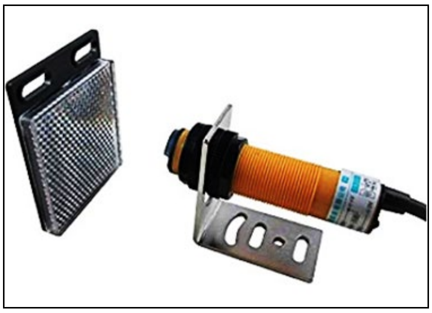

Fig 7: Photoelectric Switch Sensor 12-24VDC

Figure 8 shows the BRQ series that provided long detection distance of up to 30 m, between emitter and receiver.

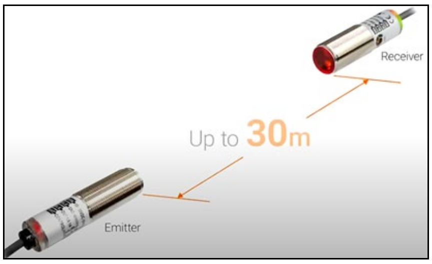

Fig 8: BRQ series photoelectric sensor

The second added value was to have a general-purpose high-power relay JQX-59F/80A relay/screw mounting relay AC220v. It was connected to protect the circuit from overloading. Figure 9 shows the used relay.
Furthermore, three main situations caused problems. The first was having the electric power of the building turned off. The second was having a person stand in front of either one of photoelectric switches without completely exiting or entering. The third one was having more than one person simultaneously entering or exiting. The system should be restarted. The optimum way to have the system work correctly was to have persons pass in front of photoelectric switches one by one in any direction.

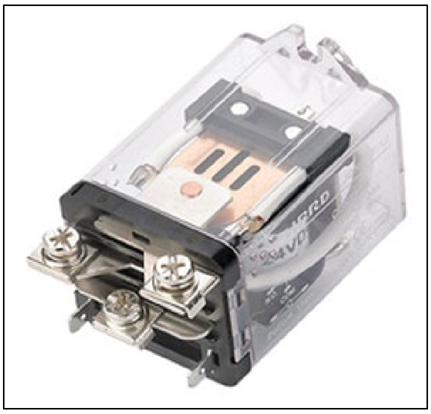

Fig 9: High-Power Relay JQX-59F/80A relay/screw mounting relay AC220v

6. Conclusions and Future Work

Electricity is one of the most important resources in the world. Visitor counter is used to automatically minimize electricity wastage, which affects the environment directly and indirectly. It reduces the bills of electric power usage. It also exhibits an effect on non-renewable resources, which are sweeping out from the earth for the need of mankind. The main objective of this research is to develop a framework that rectifies visitor counter system problems. The presented device is ready for production. The proposed framework uses Photoelectric Switch. The most appropriate distance between the two switches is one meter. The author plans to connect his device with other smart home devices, in order to increase home security. The next step is to move forward towards tailoring the sensing devices to improve the shape and size of connections to the circuit.

7. Acknowledgement

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