IMPLEMENTATION OF PASSIVE INFRARED SENSOR IN STREET LIGHTING AUTOMATION SYSTEM

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ABSTRACT
This paper presents a smart street lighting system which provides a safe night time environment for all road users and pedestrian. The main objectives are to build an automation system of street lighting using a low-cost microcontroller which is Arduino and to achieve energy-saving. Light Emitting Diode (LED) is represented as the light module. This system is controlled according to the specific mode. These modes are controlled by two sensors which are Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensor. This system can automatically turn on and off the lights according to traffic flow. This system operates during the night and the focus is only for the one-way road at a junction. Street light will be on when only there is road user otherwise, it will turn off. This design can save a great amount of electricity or energy consumption compared to conventional street lights that keep alight during nights. Moreover, the maintenance cost can be reduced and lifespan of the system will increase. As the result, the system has been successfully designed and implemented as a model system.

Keywords: arduino, PIR sensor, LDR sensor, light emitting diode, energy-saving.

INTRODUCTION
Nowadays, street lighting is essential for all areas whether urban or rural since people know that street light is an alternative during the day night in order to keep the safety of the road users. Street lights management control is quite simple, yet as the urbanization, the number of streets increased rapidly [1]. The traditional lighting street lamp on-off control is based on chronological time, which may inefficient and inflexible.

The existing street lighting control system used timer and photocell. The timer is set up to turn on the street light within 7.00 p.m. until 7.00 a.m. Meanwhile, photocell reacts based on the presence of light or electromagnetic energy. In a rainy day or when the light intensity is low, the photocell will energize the contact and automatically turn on the street lights. This system is quite inefficient since the condition of day and night is uncertain. Sometimes at 7.00 p.m. the day is still bright but the street light is already switched on. In contrast, at 7.00 a.m. the street light is already switched off although the day is still dark. Thus, this system is quite inefficient.

Figure-1. Power consumption for each hour at the urban city, traffic routes and highways [9].
Table 1. Comparison energy consumption between LED and other types of lamps [5].

<table>
<thead>
<tr>
<th>Type of Lamp</th>
<th>Luminous Efficiency in m/W</th>
<th>Color-Rendering Properties</th>
<th>Lamp Life in hrs</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Pressure Mercury Vapor (MV)</td>
<td>35-651</td>
<td>Fair</td>
<td>10,000-15,000</td>
<td>High energy use, poor lamp life</td>
</tr>
<tr>
<td>Metal Halide (MH)</td>
<td>70-1301</td>
<td>Excellent</td>
<td>8,000-12,000</td>
<td>High luminous efficiency, poor lamp life</td>
</tr>
<tr>
<td>High Pressure Sodium Vapor (HPSV)</td>
<td>50-1501</td>
<td>Fair</td>
<td>15,000-24,000</td>
<td>Energy-efficient, poor color rendering</td>
</tr>
<tr>
<td>Low Pressure Sodium Vapor</td>
<td>100-1901</td>
<td>Very Poor</td>
<td>18,000-24,000</td>
<td>Energy-efficient, very poor color rendering</td>
</tr>
<tr>
<td>Low Pressure Mercury Fluorescent Tubular Lamp (T12 &amp; T8)</td>
<td>30-901</td>
<td>Good</td>
<td>5,000-10,000</td>
<td>Poor lamp life, medium energy usage, only available in low wattage</td>
</tr>
<tr>
<td>Energy-efficient Fluorescent Tubular Lamp (T5)</td>
<td>100-1201</td>
<td>Very Good</td>
<td>15,000-20,000</td>
<td>Energy-efficient, long lamp life, only available in low wattage</td>
</tr>
<tr>
<td>Light Emitting Diode (LED)</td>
<td>70-1601</td>
<td>Good</td>
<td>40,000-90,000</td>
<td>High energy savings, low maintenance, long life, no mercury. High investment cost, nascent technology</td>
</tr>
</tbody>
</table>

**METHODOLOGY**

**Design architecture**

The system development starts with the design architecture of the proposed system. The block diagram of this system is as shown in Figure-2. The components for this project have been classified based on the components group consists of input, output and controller. Sensors are used to control the desired system parameters. Next, the sensors will transfer the gathered information into the controller which runs the software in order to analyse the system. Meanwhile, the purpose of the microcontroller is to gather the data from the street light and transfer it as the output of the system.

**Hardware specification**

In hardware specification, Arduino Uno has been selected as the controller for this system due to its low cost, compact size, compatibility, easy interfacing over several other type of controller including Programmable Integrated Circuit (PIC), Programmable Logic Controller (PLC) and others. Arduino is an open-source hardware kit with 8-bit Atmel AVR pre-programmed on-board microcontroller kit. It comes with boot loader which uploads programs into microcontroller memory. Figure-3 shows the diagram of Arduino Uno.

**Figure-2. Block diagram of street lighting of automation system.**

![Diagram of Arduino Uno](image)

In the meantime, PIR sensor is a passive electronic device that detects motion by sensing infrared fluctuations. It is made up of crystalline material which generates surface electric charge when exposing to heat in the form of infrared [8]. PIR sensor allowed to sense motion, either vehicle or human in or out of the sensor range. This sensor is quite small, inexpensive, easy to use, low power and easy to interface with. Figure-4 and Figure-5 show the diagram of LDR sensor and PIR sensor respectively.
Figure-4. Diagram of LDR sensor [8].

Figure-5. Diagram of PIR sensor.

Figure-6 shows the proposed design layout of the street lighting automation system. There are 12 LEDs used as the light module, 4 PIR sensors that locate about 5cm from the light pole and 1 LDR sensor at the junction of the road to detect light intensity.

Software development

The microcontroller required a program to operate and execute the process associated with the proposed design. Arduino software has been used as the interface between software and hardware of this project. This Arduino version 1.0.6 makes it easy to write and upload the code to the board. It can be used in any Arduino board and written in Java. There is simple step to verify, compile and upload after writing the code and simply know either the code written contains error or not.

The complete flowchart which indicates the whole operation of the system and controlled by two modes is as shown in Figure-7. These modes are controlled by two sensors which are LDR and PIR sensor. The focus of this project is only a one-way road at a junction and it will detect any movement either vehicle or pedestrian.

Firstly, Mode 1 will be selected when LDR detect day or night. If it senses night, automatically the street lights at the junction of the road (L1, L2, L3 and L4) and all PIR sensors will be switched on. Next, Mode 2 will take over when each PIR sensor at any point senses the motion or any movement of the vehicle within 5 metres. Arduino microcontroller will switch on the street lights at the edge of the road. The street lights will turn on until the PIR sensor does not sense any movement within 10 seconds, therefore street lights will be turned off. When LDR sensor senses the intensity of light from the sun, the system will turn off both street lights and PIR sensor. Lastly, the system will loop to the initial condition.

Figure-7. Flowchart of the system.
The complete schematic diagram of proposed design system is as shown in Figure-8.

![Complete schematic diagram of the system](image)

**Figure-8.** Complete schematic diagram of the system.

**RESULT AND DISCUSSION**

**Hardware testing**

A prototype of the street lighting automation system is developed and the whole prototype design is as shown in Figure-9. The design of the whole project was done with 12 LEDs, 4 PIR sensors and 1 LDR sensor. All the wiring and connection are connected to Arduino board. This was done by calibrating part by part which is started with LDR sensor, then PIR sensor and lastly LED as the light module. During a day, all LEDs and PIR sensor is turned off. This condition is shown in Figure-10.

![Prototype of proposed design project](image)

**Figure-9.** Prototype of proposed design project.

Meanwhile during the night, whereby LDR sensor detects light intensity, 4 LEDs at the junction be turned on. This condition is on Mode 1. Figure-11 shows the condition of LEDs turned on during the night.

![Condition during night, 4 LEDs at the junction turn on](image)

**Figure-10.** Condition during day.

For Mode 2, PIR sensor will detect any movement of vehicles or pedestrians, then, LEDs will turn on. When PIR sensor 1 detects movement, LED 5 and LED 6 is turned on. This condition is as shown in Figure-12. Figure-13 shows the LED 7 and LED 8 turned on when PIR sensor 2 detect movement. Figure-14 however, shows the LED 9 and LED 10 turned on when PIR sensor 3 detect movement. And lastly Figure-15 shows both LED 11 and LED 12 turned on when PIR sensor 4 detect movement. The system then will loop to the initial condition.

![Condition during night, 4 LEDs at the junction turn on](image)

**Figure-11.** Condition during night, 4 LEDs at the junction turn on.
Figure-12. LED 5 and LED 6 turned on when PIR sensor 1 detect movement.

Figure-13. LED 7 and LED 8 turned on when PIR sensor 2 detect movement.

Figure-14. LED 9 and LED 10 turned on when PIR sensor 3 detect movement.

Figure-15. LED 11 and LED 12 turned on when PIR sensor 4 detect movement.

Energy utilization

For this street lighting automation system, the usage of energy or power can be less than the normal power consumption that have been analysed in existing street lighting since this system is using smart street lighting which only light up if there is vehicle or pedestrian. Regardless it is during peak hour on the night such as from 7.00 p.m. until 12.00 a.m. in the midnight. Plus, this system is using LED as the light module which is better in saving energy compared to the existing lamps.

Assuming the street lighting functioning completely 12 hours within 7.00 p.m. until 7.00 a.m. Assuming 12 nodes are used to be working power consumed and is given as below.

Using High Pressure Sodium (HPS)

Total power consumed by 1 HPS = 400W
Number of nodes = 12
Number of working hours per day = 12
Power consumed per day = 12 x 12 x 400 = 57.6 kWh = 57.6 units

57.6 x 30 = 1728 units per month = 1728 kWh/month

Using LED

Total power consumed by 1 LED = 200W
Number of nodes = 12
Number of working hours per day = 12
Power consumed per day = 12 x 12 x 200 = 28.8 kWh = 28.8 units

28.8 x 30 = 864 units per month = 864 kWh/month

Using LED (for street lighting automation system)

Total power consumed by 1 LED = 200W
Number of nodes = 4 (fully light on for 12 hours)
8 (light on when sensor detect movement)

Number of working hours per day (for sensor):
 Assume :7.00 p.m. – 1.00 a.m. (heavy traffic)
= 6 hours
= 1.00 a.m. – 7.00 a.m.
= 3 hours (within 30 minutes vehicles pass through)
Total = 9 hours

Power consumed per day = [(8 x 9) + (4 x 12)] x 200
= 24 kWh
= 24 units
24 x 30 = 720 units per month = 720 kWh/month

Energy saved between LED for automation system with HPS for public street lighting:
1728 – 720 = 1008
1008 \times 100\% = 58.33\%

Energy saved between LED for automation system with LED for public street lighting:
864 – 720 = 144
144 \times 100\% = 16.67\%

Table-2. Comparison of energy saving between LED and HPS.

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Meanwhile, for the street lighting automation system, the assumption is made, whereby within 7.00 p.m. until 1.00 a.m. which is heavy traffic during the night, the system will turn on for 6 hours. During midnight, at 1.00 a.m. until 7.00 a.m., assumed that every 30 minutes, there are vehicles used the road within each 1 hour since fewer people used the road during midnight.

From this calculation, comparison of the energy saved between HPS lamps and LED lamp is obtained. About 16.67 % energy can be saved when compared LED for street lighting automation system with LED used for public street lighting. However, 58.33 % energy can be saved when compared LED for street lighting automation system with HPS used for public street lighting. The difference value between usages of HPS lamps quite high compared than the usage of LED. Consequently, usage of LED gives more energy saving compared than High Pressure Sodium (HPS) lamps.

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Estimated power saving calculation
Cost of controller = RM 182.10

Saving per month (RM):
= (kWh (not installing PIR sensor) – kWh (installing PIR sensor) x 0.192 sen
= (864 – 720) x 0.192
= RM 27.65

Operation cost per month (RM):
= kWh x 24 hours x 30 days x 0.192 x 4 PIR sensor
= 0.024 x 9 x 30 x 0.192 x 4
= RM 4.98

Saving per year (RM):
= (27.65 x 12) – (4.98 x 12)
= RM 272.04

Simple Payback Period (SPP)
SPP = Cost of controller / Savings per year
= 182.10 / 272.04
= 0.669 years

The calculation is based on Malaysian street lighting tariff that shows the calculation of energy saving for street lighting automation system and simple payback period (SPP) [10]. From the calculation, approximately 0.669 years are required to recover the initial investment through project savings. Therefore, the simple payback period of automation system will reduce for installation in the large area compared to the small area.

CONCLUSIONS
By referring all the results, it can be concluded that both hardware and software development of this project meet the objective of design. A working prototype of street lighting automation system was successfully built using Arduino Uno. Usage of PIR sensor as the input gives energy saving to the system since LED turn on only when there is movement from vehicles, thus, the usage of power consumption by LED decreases. About 16.67 % energy can be saved when compared LED for street lighting automation system with LED used for public street lighting. However, 58.33 % energy can be saved when
compared LED for street lighting automation system with HPS used for public street lighting.

For future development, this system can be upgraded for two ways road especially in highways, traffic routes and urban areas.

REFERENCES


