Design and Realization of a Intelligent Lighting System for a Smart city Based on Ultrasonic Waves

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Abstract— **This article presents an intelligent lighting system that can autonomously control the lighting level of lamps by using data of vehicles (bus, car, motorcycle and bicycle) and / or pedestrian circulation in a specific area. The system is able to adjust the lighting level as needed and reduce energy costs. Therefore, it uses local controllers, distance detectors, and video cameras and electronic devices can be added for video processing. That way, the inputs from the sensors are processed to reduce the lighting optimally.**

We realized our system by an Arduino card containing the intelligent lighting program developed in Arduino IDE programming environment ensuring the acquisition of the light intensity by the LDR sensor and the distance of the object by the HC-SRO4 ultrasound sensor, the control of the intensity of the LEDs varied according to the needs.

Experimental results show that compared to a traditional lighting system, the presented architecture allows energy savings up to 50%. The results of the tests obtained are very satisfactory.

Keywords— intelligent lighting system; Arduino card ; LDR sensor; HC-SRO4 ultrasound sensor.

I. Introduction

The public lighting of cities and towns is one of the main factors of the comfort and the security of the inhabitants, it represents every year the major part of the energy consumption. So for many years ,saving and controlling the electrical energy consumption for streets lighting was one of the major problems that disturbed and costed a huge losses for many governments around the world.

One of the solutions proposed is the intelligent lighting (automatic lighting), it is a first step towards the modern city or the connected city.

The European Commission's study has shown that increasing energy consumption will mainly increase cities rather than rural areas [1]. Intelligent lighting [2] is a multidisciplinary field within the Smart City framework that allows the integration of sensors [3], control technologies, in order to make efficient management of street lights. Several works have been presented in this field covering various aspects of intelligent public lighting systems. Among them, in [4], the benefits of using DC LED lamps are significant compared to traditional AC streetlights; in fact, they are characterized by longer life, lower maintenance costs, higher efficiency. The energy saving can be much higher if each lamp has an integrated solar panel [5]. Further reduction in energy consumption can be achieved if the intensity of the LED lamps is controlled by an intelligent system capable of calculating optimal lighting profiles on the basis of traffic and time information.

This aspect has been widely discussed in [6], [7] where a public lighting system based on a wireless data network has been designed to control and monitor a system containing a number of streetlights. The benefits of intelligent lighting systems are multiple; the most important is to increase energy savings. As a result, most work in this new field of study is currently focused on extracting maximum energy savings in conjunction with efficiently controlled LEDs [8, 9]. In fact, systems with energy-saving integrated lighting control typically offer 17-60% energy savings compared to traditional lighting control based on occupant usage patterns [10]. In this manuscript, you will find a simple description that gives a general ideas for the intelligent lighting systems, and show how to design and realize it using an Arduino card, ultrasonic sensors, LDR light sensor, LEDs and a mock-up to do the experience, Without forgetting the Software part of our project that it is the computer base of the intelligent lighting system.

II. Methodology

Before moving on to the design and implementation of a project, we must always know the theoretical study in order to have good results in the practical part.
In this part, we will present the block diagram and the flowchart of our project for a better understanding of its overall functioning. The operating principle of the project is illustrated in Figure 1: first we must use electronic components (HC-SR04 ultrasonic sensor, LDR light sensor, LEDS, Arduino UNO microcontroller and queues) to build the electronic circuit that achieves our goal (intelligent lighting).

- The block diagram corresponding to the overall operation of the circuit is as follows:

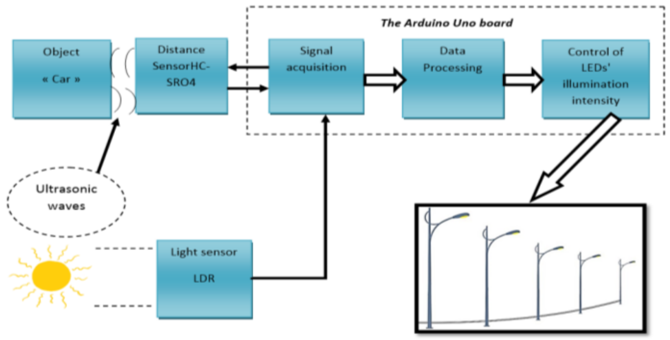

Figure 01: Block diagram of global operation of the circuit

The generation and propagation of the ultrasonic waves are entirely based on the speed of sound. The following four points show how taking a measurement of the ultrasonic sensor:

1. A HIGH pulse of 10µs is sent to the TRIGGER pin of the sensor.
2. The sensor then sends a series of 8 ultrasonic pulses at 40KH
3. The ultrasound propagates through the air until it touches an obstacle and returns in the other direction to the sensor.
4. The sensor detects the echo and closes the measurement.

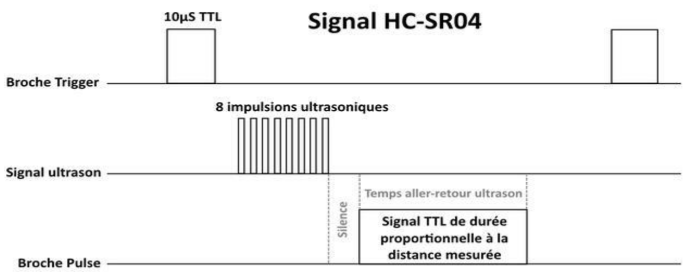

Figure 02: Illustration of the incoming / outgoing signal of an HC-SR04 sensor

The signal on the ECHO pin of the sensor remains HIGH during steps 3 and 4, which makes it possible to measure the duration of the round trip of the ultrasound and thus to determine the distance.

Each time the distance between the object and the sensor decreased, the intensity of the LED will increase and vice versa, We developed a formula that allowed us to define the relationship between the object distance and the intensity lighting :

$$\text{Intensity} = (K * 5) / D.$$

• K: is a lighting constant.
• D: measured distance.

Distance has a relationship with speed and time knowing that:

$$D = V * T.$$

• D = distance of object in cm
• V = the speed of the ultrasound waves in meter / sec
• T = the time in seconds.

If the LDR output <Vref → (daytime) → lamp intensity = 0v and if the LDR output> Vref (Darkness) → the intensity of the LED lamp varies depending on the distance between the HC-SR04 distance sensor and the object.

The following figure illustrates the flowchart of our project that provides intelligent lighting.

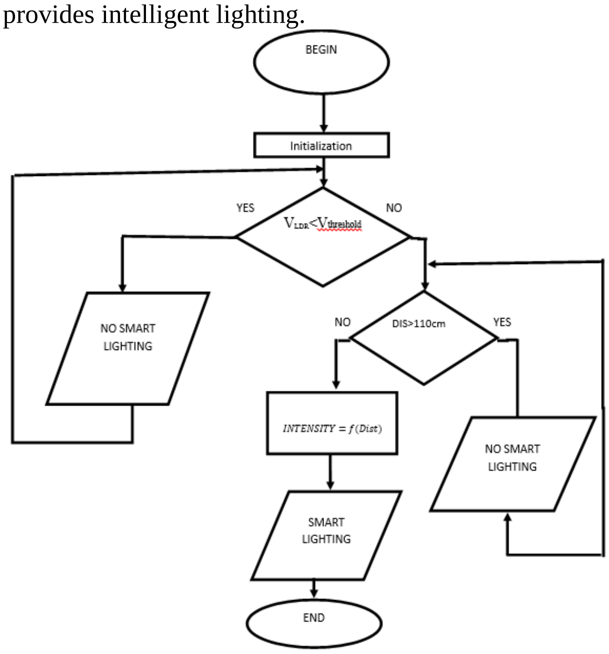

Figure 03: The flowchart of the intelligent lighting system.

The flowchart consists of two main conditions:
-The first condition concerning the VLDR (the voltage obtained by converting the quantity of the light received into voltage): if this voltage is lower than V threshold = 4.5V, then automatically there is no intelligent lighting because the light of sun is sufficient (day), on the other hand if it is checked (night), we pass to the second condition concerning the distance:
- If the distance is greater than 110cm (our choice) then the LEDs remain off (no intelligent lighting), otherwise (distance less than 110cm): the LEDs will be illuminated according to the distance between the sensor HC-SRO4 and the 'object.

In this project we have the possibility to control the LEDs in parallel or in an individual way.
After having theoretically studied the HC-RSO4 ultrasound sensor, we are now interested in the LDR sensor circuit (which converts a light signal into an electrical signal) in order to better understand its operation and its light sensitivity, So we used two montage to get the R_ldr. The diagrams are given below:

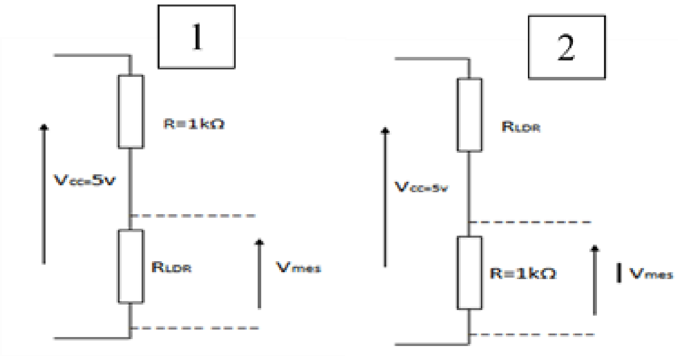

Figure 04: The voltage divider mounts

According to the law of voltage divider, we obtained these relations:
The first montage:

$$v_{mes} = \frac{R_{ldr}}{R+R_{ldr}} \cdot v_{cc}$$

The second montage:

$$v_{mes} = \frac{R}{R+R_{ldr}} \cdot v_{cc}$$

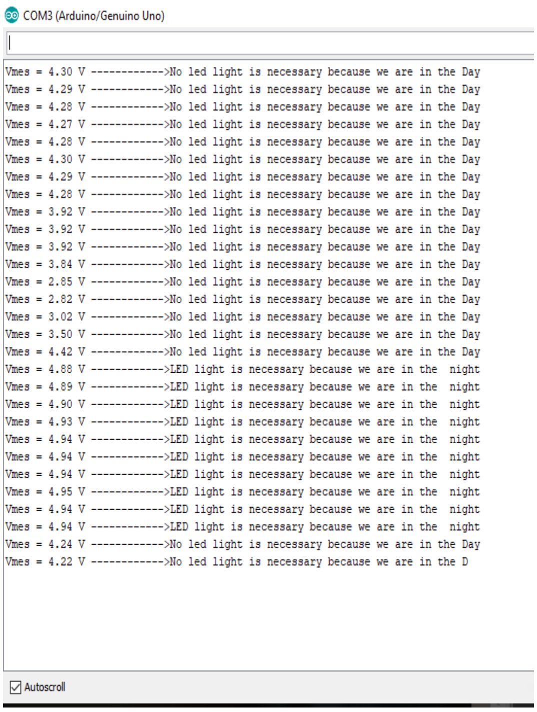

Figure 05: the variation of the measured voltage according to the intensity of the light captured

We have noticed that
1-the values of Vmes are calculated before the 2 experiments, by a simple test on the operation of the LDR sensor. The test allows to display and know the voltage corresponding to each quantity of light captured by this sensor.
2-the values of R_ldr in the 1st montage are increasing and decreasing in the 2nd.

Simulation:

The following figure shows the project simulation montage under Proteus.

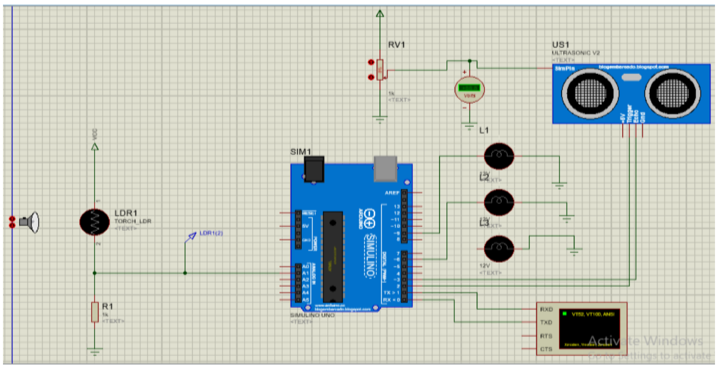

Figure 06: Project simulation

The montage consists of three parts, the Arduino card with the lamps, the LDR sensor circuit and the ultrasonic sensor circuit.

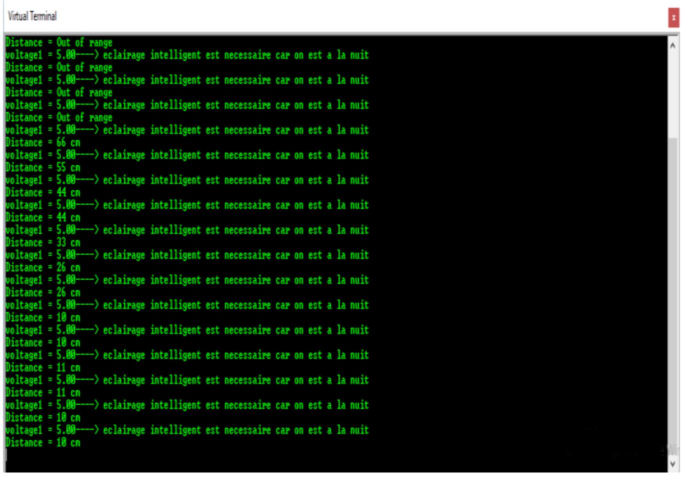

Figure 07: illustrates the display monitor of the simulation distance.

III. Results and discussion :

To do this task, We used the equipment we talked about previously :an Arduino Uno board, an HC-SRO4 ultrasonic sensor, queues, a test plate, LEDs, an LDR light sensor, resistors and the software: Arduino 1.8.6 hourly build.

Figure 08: Software and hardware used

After the assembly and the wiring of the material in a model (that was made of wood) and the launching of the program in the Arduino card we obtained the following result:

Figure 09: Project realization

- In this part , we did 3 experiments: our first objective is making sure that there is a Positive relationship between the led light and distance ; the second objective is to know the tolerance between the real distance and the other measured by the sensor, with another way: to know the degree of precision of the sensor HC-SRO4. The results obtained are shown in the following images:

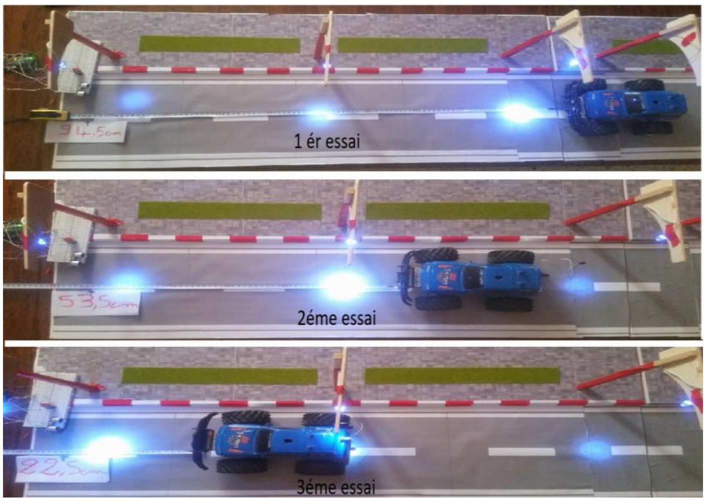

Figure 10: real values of distance

From these three experiments, we note that the intensity of the LEDs varies according to the car distance; so this part validates the positive relationship between (led light, car distance) and the good functioning of our intelligent lighting system.

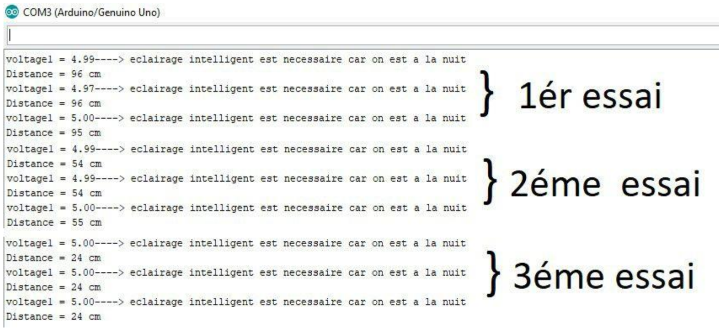

Figure 11: Values measured by the HC-SRO4 sensor

From Figures 10 and 11, we can now calculate the tolerance between the real values and the others measured by the HC-SRO4 sensor:

	the distance values measured by the sensor (cm)	Real values of distance (cm)	Error [cm]
1st try	94.5	96	1.5
2nd try	53.5	54	0.5
3rd try	22.5	24	1.5

Table II.1: Tolerance between values measured by HC SRO4 and actual values

IV. Conclusion

This work allowed us a good understanding of the intelligent lighting system and the different physical mechanisms of the ultrasonic waves.

We realized our system by an Arduino card containing the intelligent lighting program developed in Arduino IDE programming environment ensuring the acquisition of the light intensity and the distance of the object, the control of the intensity of the LEDs varied according to the object distance .

The results of the tests obtained are very satisfactory. This work also allowed us to detail practical aspects of communication between the Arduino UNO and its IDE via the USB port for serial communication. So this work gives a possible and very effective solution for optimal control of public lighting that will allow us to minimize energy consumption.

Our project gave us the opportunity to address fundamental aspects of analog and digital applied electronics to smart public lighting instrumentation.

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