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Interactive System of LED-Studs for Road Signaling Using Adriano Platform and C++ Programming Language

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-ABSTRACT-

This study presents the elaboration of a Lighting Emission Diode (LED)-stud interactive system for road signaling. The prototype is based in Arduino platform programmed in C++ language. The electronic circuit is powered by solar energy, which receives and retransmits information pre-defined by the user to the other road studs via Global System of Mobile Communications (GSM) module. The road studs were designed and three-dimensionally printed (3DP) using yellow polylactic-acid (PLA) filament, however the proposed circuit can also internally integrate other conventional road studs. The solar panel connected to an internal battery for independent power storage was able to power the electronic circuit during 12 uninterrupted hours. The results show that, in addition to the luminous interactivity set by the user as desired, the prototype in question exceeds the brightness and reflectivity light levels of conventional road studs, thereby improving the driver's perception of the track, thus reducing the risk of causing accidents.

KEYWORDS *- Led-Stud, Luminous interactivity, Road safety, Signaling, Traffic control and management.*

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I. INTRODUCTION

There is an increase in the number of fatalities and accidents caused by difficult visibility, precarious signaling and adverse weather especially at night with conditions such as fog and rain, in tracks without proper soil demarcation over all extension of Brazilian road network, thereby causing a great deficit to the government. According to the World Health Organization (WHO), annually, road accidents kill 1.25 million people and injure up to 50 million people worldwide with almost 90% of traffic incidents occurring in low- and middle-income countries [1].

Road accidents result in medical costs, human losses, property damage, settlement costs (agreements and insurance) and much more [2-3]. Still according to the WHO, Brazil has the fourth largest number of deaths in the Americas, only standing behind the Dominican Republic, Belize and Venezuela. Brazil records about 47 thousand traffic deaths per year so 400,000 people are left with some kind of sequel. According to a survey made by the National Road Safety Observatory the cost to the country reaches 15 billion USD [4].

Researchers have suggested the use of Light Emitting Diode (LED) as an efficient and attractive alternative for road illumination with low energy consumption and good brightness [5-6]. LED technology creates a new opportunity to redesign road singling. Multi-source LED luminaries can be projected to make light distribution consistent with very specific road layouts [7-8]. The great benefits of LEDs in terms of light consumption and color management contribute to an increased development of LED-based applications [9-10]. The illumination using LEDs grows gradually due its economy and luminosity compared to incandescent lamps, not mentioning that the life of LEDs surpasses 30,000 hours of use and produces more than 30,000 lux [11].

In outdoor applications, a number of LED-based products have been proposed; mainly in the field of road lighting, these products can benefit drivers through traffic control devices [12-13]. The use of LEDs in road traffic projects adds value to various projects, from structural design and / or complements as security items, providing diverse utile applications, assisting the driver’s clear and objective perception of the track [14-15-16].
So traffic management and road safety can benefit from LED technology, but for its true effectiveness, the system should be luminous intensity efficient, providing visual comfort without strong brightness, regardless the environmental conditions [17-18-19]. LED-studs can improve vehicle orientation at night in terms of lateral control of vehicles in curves. For example, interactive lights on the roads can warn drivers about someone

driving in the wrong way; colored (yellow) or intermittent lights can guide drivers during rain or fog, or even indicate specific areas such as railroad crossings [20-21].

The lack of safety on Brazilian highways due to adverse weather, the precariousness of vertical signs (visible and legible plates and / or nonexistent or low lighting efficiency). Nowadays, new technologies have been used to accidents negative data, so this study seeks to demonstrate an interactive system for the reduction of road accidents. The main objective of this study is to propose a luminous system intended to help traffic management, improving driver's perception of the road. The prototype is based in Arduino platform programmed in C++ language and introduces a network of wireless LED-studs, remotely controllable from an online platform. The conceptual free online platform transmit commands to the road studs through GSM connection, a coordinating unit receives the commands through a GSM platform modem, and then transmits the relevant data to the other LED-studs installed on the road, the user can reconfigures the settings in terms of color, brightness and frequency of flashing (pulsing) as desired.

II. MATERIALS AND METHODS

2.1 Materials

Table 1 shows the materials used for the construction of the conceptual prototype:

Table 1. Materials used to construct each unit of interactive road LED-studs

Item	Material description	Quantity
1	Arduino One board	2
2	Solar board-5 volts	1
3	Rechargeable battery-9 volts	1
4	Dc / step converter upMt3608	4
5	Transistors	10
6	Phenolite plate	2
7	RGB LEDs	4
8	Resistors of 330 ohms	4
9	Resistors 4.7K	4
10	Photo transistor	1
11	Potentiometer tripo7 10K	3
12	Jack connector	2
13	Adjustable dc source lm 2596 In 3.2-40v out 1.5-35v	2
14	Filament roll in PLA material	1 roll (50 meters)
15	01 USB cable to connect Arduino One to PC	1
16	Protoboard	1

2.2 Electronic circuit design

For the transmitting, a GSM (SIM800L) module was used, in addition to the low consumption, it makes the communication via serial interface, adapting to the most varied boards and microcontrollers that use this type of communication. The use of solar panels was also a great differential for this project, besides not requiring cables to interconnect the grid to the power system; the mini solar panel feeds the internal 9V rechargeable battery, which recharges during the day so the LED-stud is self sufficient at night. We used red green and blue (RGB) LEDs due color versatility as the programmer enters a function (choose colors) as desired. The Fig. 1 shows the electronic circuit diagram:

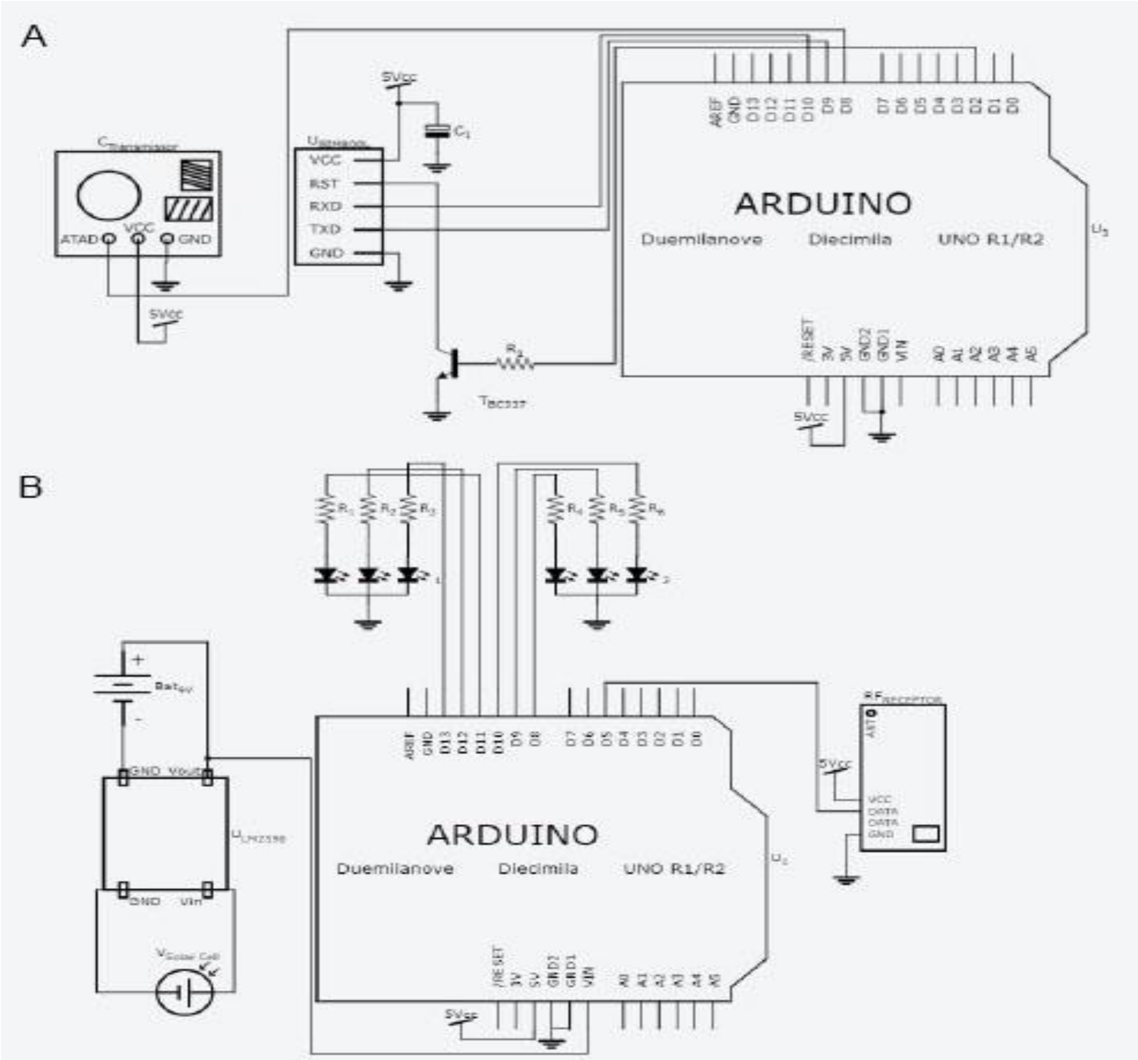

Fig. 1 Electronic diagram: (a) electronic receiver; (b) electronic transmitter.

Following the same rationality of the colors from a traditional traffic light, in the prototype the function of the red color is to warn the drivers of possible danger or obstructions in the track, the yellow color means alert, careful; and the function of the green color is free runway. The settings are defined by the user in according to the source code (color/on-off/flashing, etc.). For example: when the "red LED on" command is activated, it will be active during 01 second, and it will turn off and on again in a loop until it is interrupted by the function "off", the same will happen for the other colors. So the other LED-studs will receive the defined programming language set by the user, since these are connected in series by RF, wireless or Bluetooth module, or other; in this case we used a GSM module.

2.3 Arduino C++ programming language

The control of the luminous interactivity of the LED-stud system was programmed using C++ language in Arduino platform. The C++ presents several key elements of object-oriented programming [22]. The Arduino platform has numerous applications in several areas, both technological and for private use; it is an Open Source platform. Arduino platform has an Atmel AVR microcontroller with built-in input/output support, and standard programming language [23].

2.4 3D design of prototype system

For the prototype design we used Sketch UP Make2013 (free software version) and Blender 2.78 (open source free code software). For prototype printing we used a 3D Cloner Lab machine (Etech), the stud carcass was printed using a 1.75 mm yellow PLA filament (INGEO 850 Natureworks) with 1.24 g/cm^{3}density, the filament melting temperature varied from 190 °C to 220 °C. Each stud took 14 hours in total to be printed, the 2 top parts took 5:30 h and the 2 bottom parts took 1:30 h each, consuming approximately 160 meters of filament approximately (300 grams). We use acrylic lens for the emission of LED-light with input angle between, 0 and 20 degrees. The dimensions of the LED-stud are 250 mm length x 150 mm width x 50 mm height. The structural function of the carcass is only integrating the proposed circuit, it is important to emphasize that the materials chosen for the construction of the road studs must comply with technical standards [24]. The Fig. 2 demonstrates the LED-stud prototype 3D model, the internal circuit and the finished printed prototype:

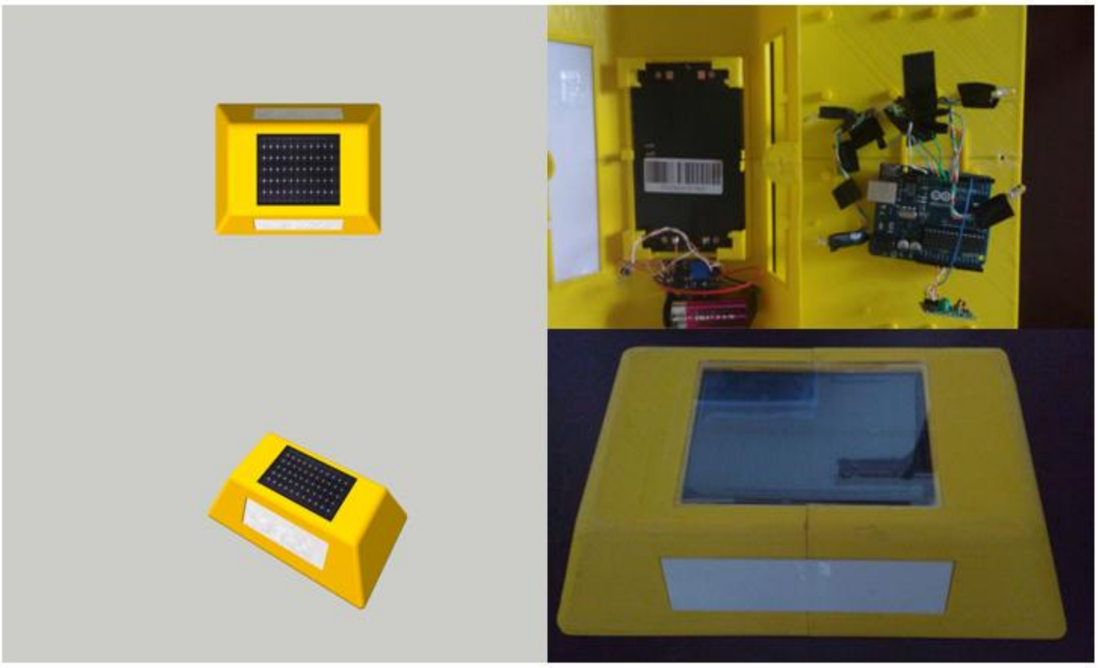

Fig. 2 LED-stud 3D model, the internal electronic circuit and the finished printed prototype

2.5 Light intensity measurement test

For the light intensity measurement, a digital lux meter (MLM-1011) with a light range of 1 to 1,000,000 lux was used, the apparatus is very sensitive so care must be taken to avoid differences or impartiality during the collection of information.

The calculation of the average luminance is given by equation 1:

$$AL = SL / N \quad \text{Eq. (1)}$$

Where:

AL = Average luminance

SL = Sum of the luminance of all measured points;

N = Number of points measured;

The methodology consisted in measuring the brightness of LED-studs only at night at an observational angle of 0.2° and horizontal angle between 0 and 20° (degrees) for each color (red, yellow, green and also blue) and to compare these values with the reflective brightness levels of conventional road studs, by reflecting the light of a static vehicle arranged at a distance of 5 meters, the brightness of the car headlight is 700 lumens, and the distance was measured using a digital laser measurer (Bosh). The luminous intensity of the LED-studs was set at maximum power in order to improve the illumination intensity. The Fig. 3 shows the LED- stud interactive prototype colors, set by the user as desired:

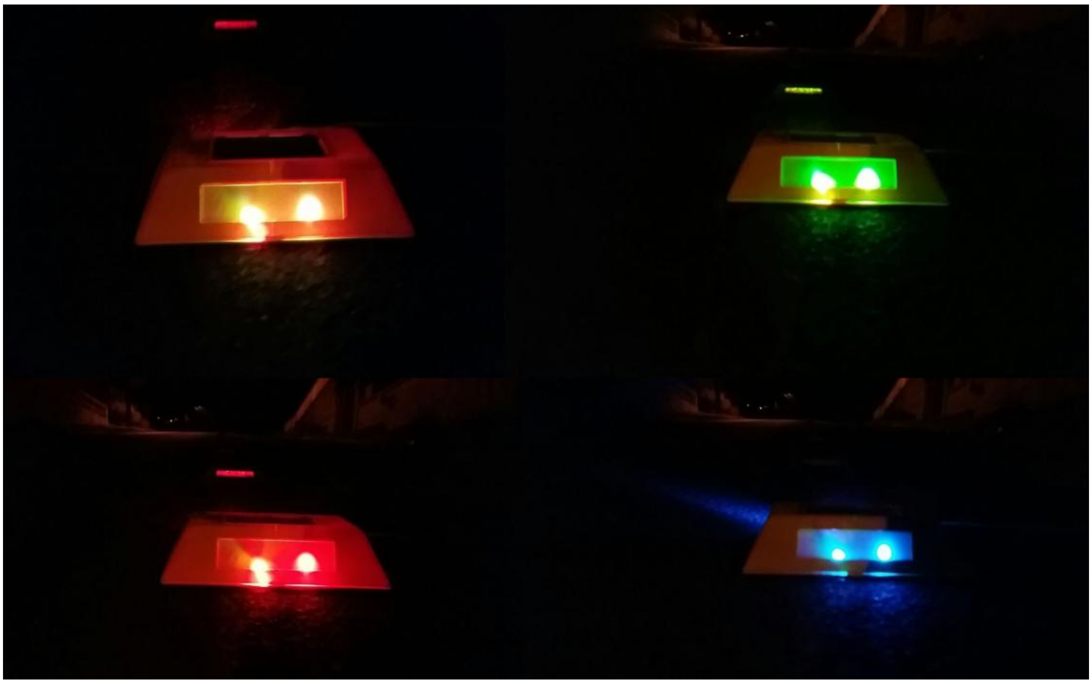

Fig. 3 LED-stud interactivity prototype option of colors

III. RESULTS AND DISCUSSION

Table 2 shows the luminous intensity in relation to the values considered desirable (ideal), for both conventional road studs and LED-stud results.

Table 2. Illumination intensity levels of road studs

Observational angle (degrees°)	Horizontal input angle (degrees°)	Light intensity coefficient (mcd/lux) Color			
		Yellow	Red	Green	Blue
0.2	0	167[a]	70[a]	93[a]	26 [a]
0.2	20	67[a]	28[a]	37[a]	10 [a]
0.2	0	594[b]	73 [b]	485 [b]	62 [b]
0.2	20	297 [b]	37 [b]	243 [b]	31 [b]
0.2	0	150[c]	52 [c]	320 [c]	43 [c]
0.2	20	66 [c]	22 [c]	49 [c]	11 [c]

[a] Value considered desired [25]; [b] conventional studs; [c] LED-stud prototype.

As can be seen, for all colors tested, the interactive LED-stud system present higher luminance intensity than the conventional road studs, which does not emit its own light, requiring that drivers focus on its reflective base, gradually reducing their perception of the road. In this view, the purposed prototype system opens doors for the application and evolution of LEDs technology for traffic control and management. Preliminary tests suggest that the road led illumination is visible from 69 meters of diatance with the minimum luminous intensity available for a surrounding horizontal illumination of 1000 lux [19].

The battery for energy storage of the prototype lasted about 12 hours, feeding the internal circuit at night and charging during day. Remembering that by using solar technology or piezoelectric devices, these systems save even more energy and the studs. Being self-powered, these studs are free from spinning problems and power supply, reducing power costs. However, technologies based on solar or piezoelectric energy are still limited in the current state of the art. The power supply of the internal circuit of the prototype system can be improved by adapting other efficient methods for energy storing, for example using a piezoelectric device taking advantage of vehicles movement and generating self-sufficient energy storage using silicon batteries. Another option is to use optic fiber to develop the stud lighting prototype based on Bragg's classical theory [29].

In the present work, mechanical resistance tests of the PLA 3D printed LED-stud carcass were not carried out because it wasn’t the main objective of study, considering that the circuit presented here can also be used inside a regular stud made of conventional material, thereby achieving the mechanical requirements specified by technical standards [24]. It’s worth mentioning that currently there are high density plastic filaments such as high density ABS, which could replace the regular building materials usually made from synthetic resin based organo-inorganic material.

LEDs technology has been gaining space and not just being a signal “on-off” in equipments, being used for decorative lighting, automotive vehicles, street lighting among others. Its ability to present adequate levels of luminance with lower energy consumption is a plus. An ideal energy consumption dimension is necessary, having that, on the road any signaling device must be visible enough for drivers to perceive them regardless the external conditions [26-27-28].

In view of the current situation of the Brazilian roads, improvements related to its precarious signposting are well seen, seeking to reduce accidents and public spending decreasing the number of accidents on highways. The proposed LED-stud interactive system is useful in adverse weather conditions such as rain and fog contributing specially at night, contributing to a better perception of drivers regarding runway signposting. New technologies appear every day, allowing adding several advances to the prototype presented here. In relation to future it is possible to propose a large scale production by integrating the proposed circuit in conventional road studs as well.

IV. CONCLUSION

The main objective of this study was to construct a LED-stud interactive system traffic management and control based on Arduino platform and C++ programming. The LED-studs were 3D designed and printed with PLA filament. The proposed circuit can also internally integrate conventional road studs made of synthetic resin in order to achieve the desired mechanical resistance in accordance with current road safety standards. The solar panel connected to an internal battery for independent power storage was able to feed the circuit during 12 uninterrupted hours. In tests, the luminous intensity of the proposed system surpasses the brightness and reflectivity levels of conventional road studs for all colors, improving the driver's perception of the track, thus reducing the risk of causing accidents.

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