Affordable digital electronics for building a hybrid dynamic marker structure with infrared illumination light patterns

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ABSTRACT

This work deals with the integration of low-cost electronic devices that were integrated into constructing a dynamic maker that allows the triggering of augmented reality events. A hybrid structure was developed to combine the most favorable aspects of fiducial markers and dynamic markers. The lighting infrared patterns are effectively modifiable through the programming of an ESP8266 microcontroller card. To test the system, an infrared lighting pattern generated was detected through a digital camera, and an augmented reality application was implemented using a web page for displaying text. Electronic shift registers were used for the temporal storage of the infrared illumination pattern. The infrared illumination marker can't be detected by human eyes, but it is easily recognized due to the inner black square shape embedded into a white wooden structure.

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1. INTRODUCTION

Augmented reality allows the addition of visual information display elements into digital environments, frequently captured through an image acquisition system. The process mainly involves recognizing and identifying a visual pattern from a digital camera to display virtual elements presented beside the real-time captured image [1]–[3]. Using available computer cameras, some efforts to enhance learning experiences have been developed to display three-dimensional (3D) virtual objects triggered from 2D pictures in a textbook using augmented reality applications [4]–[6]. The development of educational applications focused on smartphones and augmented reality has improved the students learning experience [7]–[11]. The combination of 3D graphics and virtual objects has increased the students' attention to arouse their curiosity or interest in exploring educational content [12]. To start an educational augmented reality application, commonly, a marker recognition must trigger the programmed application. Among the methods that allow the activation of different augmented reality elements, the use of static paper markers has been widely used in different educational applications [13]–[16]. Most applications combined black and white patterns to provide high contrast for identification; however, some markers have been developed using different static colors visible to human eyes [17]. Different approaches have been developed to create dynamic-colored markers that can change their patterns in time. Using thermochromic inks and heating elements was possible to create different QR color patterns for augmented reality applications [18].

On the other hand, light emitting diodes (LEDs) have remarkable advantages for data representation: low cost and low energy consumption; a long lifetime in a conveniently compact package, and a comprehensive set of commercial electronic drivers for controlling. For example, early work was focused on developing a 4×4 colored square led array to enable visual communication using continuous blinking white LEDs in corners as locators; on the other hand, red color LEDs were mounted for data information representation [19]. More recent work used an eight red-colored array, three corner blinking LEDs were used to confirm the marker location, and 4 LEDs were used for optical data transmission [20]. However, visible color LEDs activation can create light effects that distort natural and artificial environment illumination patterns; so they are usually considered intrusive elements that can also distract the user's attention. Fluorescent markers have been reported as alternative non-intrusive invisible human-eye options to trigger augmented reality applications [21]. Some infrared light, which is not visible to the human eye, has the critical advantage of not modifying ambient lighting patterns, and photographic cameras can identify and display the infrared light emission into a digital image. Interesting applications have shown the advantages of using infrared light to trigger augmented reality applications [22]–[24]. LEDs devices have a fundamental structural advantage in creating a compact light pattern: its convenient small, isolated package allows the creation of uniformly distributed arrangements.

In the past, an infrared-led cubic array microcontroller controlled has been developed to obtain distance and orientation information in a virtual reality application [25]. In general, using paper markers can represent an effective, fast prototype tool for short-term solutions. However, the manufacturing process complexity is increased for colored paper-based markers with standard or special inks [26]. This work developed a hardware-based marker to reduce paper-based drawbacks for long-term use. The ESP8266 microcontroller board can provide a stable power source using a 127 VAC to 5 VDC converter such as those used for most smartphone battery charging elements. The ESP8266 microcontroller board has one of the better performance-cost relationships in the market as an electronics prototype platform [27]–[32]. For long-term applications usage, a programmable infrared light marker avoids the needing for printing new patterns or designs and can be real-time modified using a programming routine; any consumable item is needed.

2. METHODS AND MATERIALS

A NodeMCU board with an ESP8266 chip has been selected to control the infrared light marker. For temporal storing information, two 74HC595 shift registers were selected. Fourteen infrared LEDs, IR383 of 5 mm with a 940 nm wavelength and a 20° viewing angle, were used to display the information visually. A ULN2003A circuit was used as a power interface between the 74HC595 register outputs and the infrared LEDs to handle the required current for each one. The ESP8266 microcontroller board is frequently used due to its low cost and can be easily programmed through the Arduino language [33], [34]. The system was built following the electronic diagram developed using Fritzing software [35]. For the electrical supply of the electronic devices, the 3.3 volts power supply provided by the same card with microcontroller was used, as shown in Figure 1.

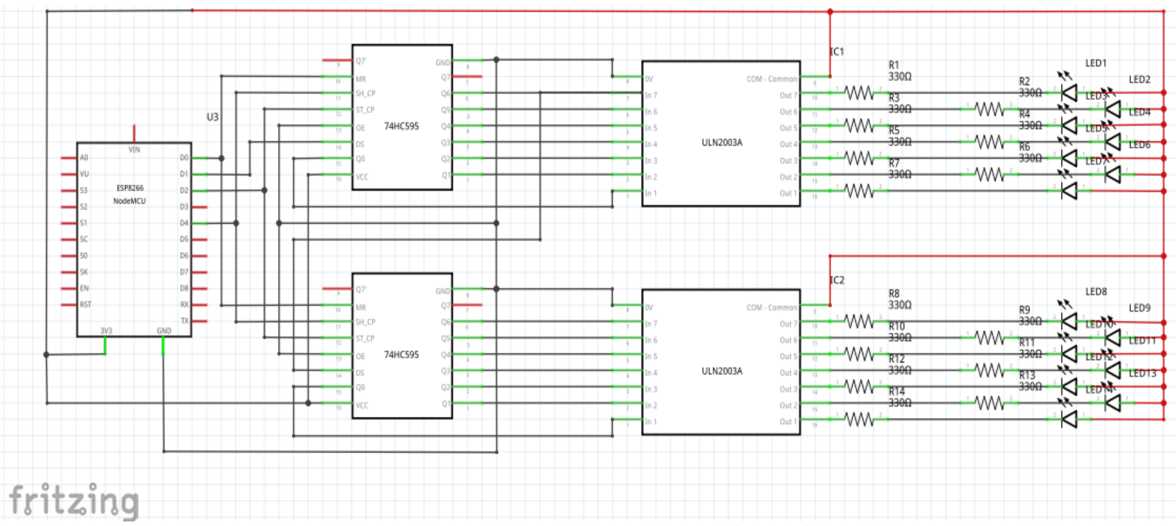

Figure 1. Electronic diagram for the infrared LEDs marker

The source code for the infrared light marker programming was implemented using the Arduino development environment based on a reduced C / C ++ language. In the first program section, the output ports which allow the clock, reset, and data signals to the first shift register 74HC595, were declared using 2, 4, 5 and 16 GPIO card pins. The detailed setup function used for programming the marker can be seen in Figure 2.

```
INFRARED_PATTERN §
int srclk = 2, rclk = 4, serial = 5, respin = 16;
void setup(){
  pinMode(srclk, OUTPUT); pinMode(rclk, OUTPUT);
  pinMode(serial, OUTPUT); pinMode(respin, OUTPUT);
  digitalWrite(respin, LOW);
  digitalWrite(respin, HIGH);
  for (int repeat = 1; repeat < 6; repeat++)
   {
```

Figure 2. Programming setup function code for the programmable marker to send data to shift registers

The base for mounting the infrared LEDs array was made using a wood square, 15 cm per side and 3 mm thickness. Black and white acrylic paint generated the marker, distributing 14 infrared LEDs into the central white square. To generate the infrared light pattern, the provided source code must be compiled and uploaded to the ESP8266 microcontroller board through a micro-USB wire. In the setup routine first section, a high level was set for the GPIO5 pin, corresponding to the shift register reset signal, which is active low. Therefore, a high level must be assured for the register reset signal before data reception.

The data bit sending routine was implemented using a for the cycle; this routine was limited to be executed only once, locating the cycle in the setup code section. The execution control for the data sending routine is carried out using the count variable "repeat" initialized in 1. When the serial format sending data is finished in the first cycle, it is incremented in 1, and for cycle starts again while the repeat variable is lower than 6. During the register programming execution cycle, used for sending the infrared lighting pattern to the marker, 3 bits are sent in serial format and can be 0 or 1 defined by code through sentences low=0 and high=1. The final generated light pattern allows the triggering of augmented reality events. The process of sending 3 bits in serial format is carried out five times, with which it is possible to send 15 data bits. However, it only is possible to visualize the last 14 bits through the infrared LEDs array.

3. RESULTS AND DISCUSSION

A low-end smartphone was used to test the infrared illumination pattern, which has an 8-megapixel camera for video and image capture. The Ar.js library [36] was used to identify the infrared illumination marker through the HTML programming language. The web-based augmented reality application was used directly through the Firefox web browser. The application allows to display a red text message "001 IR MARKER" when it is recognized using the embedded smartphone camera; webcam video capture is permanently activated through the web-based application. Once the infrared pattern is detected on the real-time image capture, augmented reality is enabled, as shown in Figure 3.

Marker recognition was performed correctly as soon as the marker was aligned with the smartphone camera, reaching a triggering distance up to 0.90 meters for the augmented reality application. Distance measurement was made from the infrared light marker surface to the smartphone camera lens. Once the camera moves away from the marker location and the infrared light pattern image is not detected on the real-time image capture, the red message disappears. It is presented until the new alignment and marker recognition with the smartphone's camera lens is matched again. In contrast with related developments reported in the literature, the presented work takes a hybrid structure to collect some favorable aspects from fiducial and dynamic markers. On the side of the fiducial markers, it considers the efficient square corner recognition through a black square detection embedded into a white surface. This avoids allocating dedicated blinking LEDs for location [16], [17]. On the side of the dynamic markers, 14 infrared led arrays are used for data transmission; different patterns can be easily programmed through a low-cost ESP8266 microcontroller, and information is indefinitely stored and presented while the energy source is active.

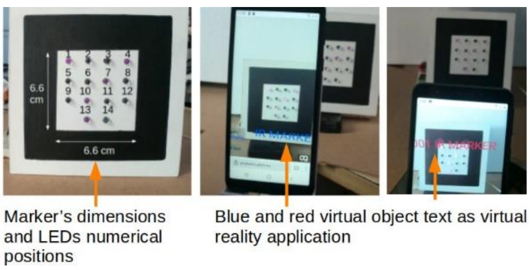

Figure 3. Identification test for the infrared marker with a smartphone

4. CONCLUSIONS

The main advantages of using the presented augmented reality triggering system can be resumed as: the whole set of hardware elements can be easily acquired due to its low-cost and high availability; students and researchers can create their own programmable infrared light marker for augmented reality applications and particular needs. Smartphone vision systems can recognize the invisible infrared light pattern generated by human eyes. The marker structure has a simple appearance, like a lightroom lamp, instead of complex, strange patterns that could distract or discourage the user's attention. The light pattern can be easily modified/adapted through an Arduino programming routine based on friendly C/C++ language, instead of considering the availability of a printer and paper to obtain new triggering patterns. The system can be expanded to increase the number of infrared LEDs due to the cascade register configuration without modifying the microcontroller board configuration, moreover selected hardware components can be driven directly through the microcontroller board 3.3 volts dc power source. The shape creates an approximate physical appearance of a domestic LED lamp used for lighting in dark conditions, in contrast to complex designs used as paper-based markers, which frequently have maze-like geometries with an intrusive appearance in recon scenes. The programmable infrared light marker is a flexible, low-cost, non-intrusive tool for long-term augmented reality trigger applications.

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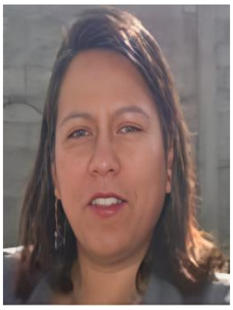

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