Interactive Light and Sound Table

An EPS@ISEP Project

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***Abstract*—Interactive products are appealing objects in a technology-driven society and the offer in the market is wide and varied. Most of the existing interactive products only provide either light or sound experiences. Therefore, the goal of this project was to develop a product aimed for children combining both features. This project was developed by a team of four third-year students with different engineering backgrounds and nationalities during the European Project Semester at ISEP (EPS@ISEP) in 2012. This paper presents the process that led to the development of an interactive sound table that combines nine identical interaction blocks, a control block and a sound block. Each interaction block works independently and is composed of four light emitting diodes (LED) and one infrared (IR) sensor. The control is performed by an Arduino microcontroller and the sound block includes a music shield and a pair of loud speakers. A number of tests were carried out to assess whether the controller, IR sensors, LED, music shield and speakers work together properly and if the ensemble was a viable interactive light and sound device for children.**

Keywords—project-based learning, teamwork, 3D user interface, IR sensing, light and sound stimuli.

I. Introduction

This paper reports on the design and development process of an interactive light and sound table by a team of four third year students from diverse engineering and cultural backgrounds during the spring semester of 2012 [1].

The goal of this project was to create an interactive product being practical (a table), entertaining (light and sound) and stimulating for children. The user should be able to control the sound played, volume and the light brightness with a single hand movement. The specified project requirements, which were intentionally broad to allow the team to make design choices, included: (*i*) to provide a natural user interface with 3D hand location awareness, *i.e.* the sound played and the lighted table area depend on the (X, Y) coordinates and the light brightness and the sound volume depend on the Z coordinate of the user hand location over the table top; (*ii*) to be safe and robust for children; and (*iii*) to comply with a 500 € budget.

Given these ideas, this document is organized in seven sections: (*i*) the introduction; (*ii*) the state of the art, where related products are described; (*iii*) the technologies used; (*iv*) the methodology adopted; (*v*) the implementation and testing, where the results of the tests performed to the table are presented; (*vi*) the future developments, including suggestions for products and applications that may derive from the project, and, (*vii*) on section the conclusions are drawn.

II. State of the Art

Although there are similar products available, they do not match exactly the proposed system. Currently there are two types of interactive tables: the multi-touch Liquid Cristal Display (LCD) and the infrared (IR) sensors / Light Emitting Diodes (LED) based interactive tables [8] Figure 1 presents a multi-touch LCD display table. These can have many different usages, *e.g.* they can be used as a touch screen monitor or as displays. It is a commercial computing platform that enables people to use touch and real world objects to share digital content at the same time [9][10].

Figure 1 – Microsoft's touch-screen tabletop PC called "Surface" [2].

On the other hand, the tables with LED lights can show different lights and some simple patterns (Figure 2).

Figure 2 – Interactive LED coffee table called "The Wave" [3].

The biggest advantage of LED light tables is that they are much cheaper. As a result, taking into account the budget and the goal, this project adopted the LED light table approach.

III. Technologies

The technologies involved include LED, IR proximity sensors, a microcontroller (Arduino) and sound playing hardware.

A LED is a p-n junction solid-state semiconductor diode that emits light when current flows through the device. White LED devices ordinarily require a 3.6 V Direct Current (DC) voltage, consume approximately 30 mA of current and have a power dissipation of approximately 100 mW. The positive voltage lead is connected to one side of the LED semiconductor through the anode and the other side of the semiconductor is attached to the top of the anvil or the negative power lead (cathode). It is the chemical composition of the LED semiconductor that determines the colour of the light as well as the brightness level. The epoxy resin enclosure allows most of the light to escape from the elements and protects the LED. Furthermore, a light-emitting diode does not have any moving parts, which makes the device extremely resistant to damage due to vibration and shocks. These characteristics make it ideal for purposes that demand reliability and robustness. LED therefore can be deemed invulnerable to catastrophic failure when operated within design parameters [7]. Infrared proximity sensors emit an infrared signal and determine the distance to an obstacle by measuring the value of the reflected signal. The reflected beam is directed through the lens to the position-sensitive detector and the sensor outputs a value reflecting the distance measured [4][5].

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software [6]. It is intended for artists, designers, hobbyists or anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or communicate with software running on a computer. The boards can be built by hand or purchased preassembled; the software can be downloaded for free. The hardware reference designs are available under an open-source license.

This set of technologies is simple to use and cheaper than the alternatives. In particular, the choice of infrared proximity rather than the ultra sonic sensors and LED instead of ordinary light bulbs results from the fact that the table will be covered with glass and the LED warm up immediately. The sensors, light and sound will be controlled by Arduino.

IV. Methodology

This section reports on the adopted step by step implementation approach, which covered the selection and acquisition of components, the design of system architecture and modules, the hardware assembly and software programming.

Table 1 presents the list and price of the components selected for the prototype. The overall cost of the material was 285.69 € (384.45 USD).

Table 1 – List of materials

Quantity	Description	Price (€)
1	IKEA Table – Lack (white)	24.99
2	ULN2003 Darlington transistor	1,20
1	Glass 55 cm x 55 cm x 0.5 cm	0.00
1	Arduino Mega 2560 REV. 3	47,97
9	IR proximity sensor Sharp GP2Y0A21	132,29
36	LED (reused)	0.00
1	SparkFun Music Instrument Shield	28,23
1	Arduino Stackable Header Kit	1,72
1	NOX ATX Urano 450 W Power Supply	31.70
1	SparkFun Jumper Wires Pack	17,59
2	Philips 6G3BII loud speakers (reused)	0.00

A. Architecture

Figure 3 presents the overall architecture of the interactive table. The system is composed of three different main modules: (*i*) the controller; (*ii*) the sound block composed of the Music Instrument Shield and the speakers; and (*iii*) the nine light and IR blocks containing one IR sensor and four LED each.

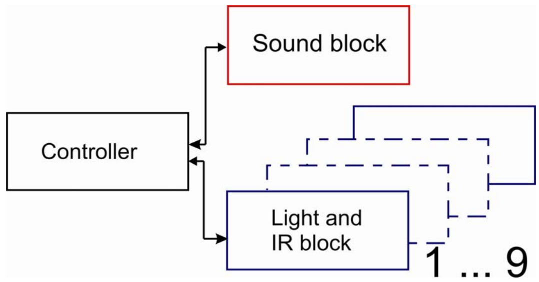

Figure 3 – Overview of the interactive table architecture.

Figure 4 presents the detailed architecture of the prototype.

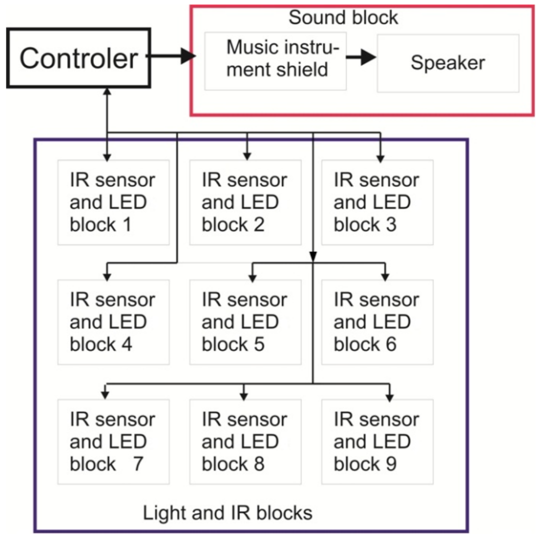

Figure 4 – Layout of the interactive sound table.

B. Control

The Arduino uses the inputs from the IR sensors to control the interactive light and sound blocks according to the flowchart presented in Figure 5. The two main functions are "Read sensor and change LED" and "Play sound".

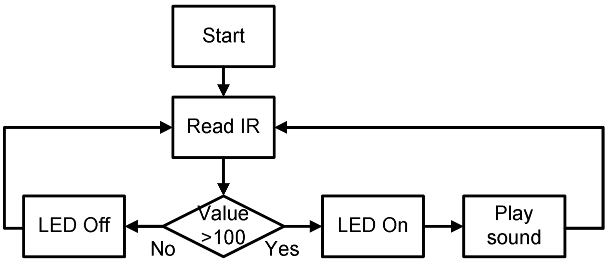

Figure 5 – Control flowchart.

Each IR sensor is connected to one Arduino analogue pin. The LED status and brightness of each block depends of this value. If value is greater than 100, the LED turns on; otherwise the LED turns off. The corresponding code is presented in Figure 6.

```
void read_sensor_and_change_led(
  int analogPin, int ledPin) {
     int val_a0 = analogRead(analogPin);
     double val = 0;
     if (val_a0 > 100) {
       double val = val_a0-100;
       if (val < 550) {
         val = val/550 * 255;
         val = round(val);
       } else { val = 255; }
       analogWrite(ledPin, val); // LED on
     } else {
       digitalWrite(ledPin, LOW); // LED off
     }
}
```

Figure 6 – "Read sensor and change LED" function.

Using the music shield, a different instrument was attributed to each block. Whenever the IR sensor reading of a block is greater than 100, the system selects the corresponding instrument and then plays in different notes the value of the IR sensor. The corresponding code is presented in Figure 7.

```
void play_sound(int number, int instrument)
{
  talkMIDI(0xC0, instrument, 0);
  int sensorValue = analogRead(number);
  if (sensorValue < 100) {goto ending;}
  Serial.println(sensorValue);
  delay(1);
  note = sensorValue/3;
  noteOn(0, note, 100);
  delay(50);
  noteOff(0, note, 100);
  ending:
  delay(50);
}
```

Figure 7 – "Play sound" function.

C. Table Layout

Figure 8 presents the table top dimensions and drilling holes, where circles represent LED and rectangles IR sensors.

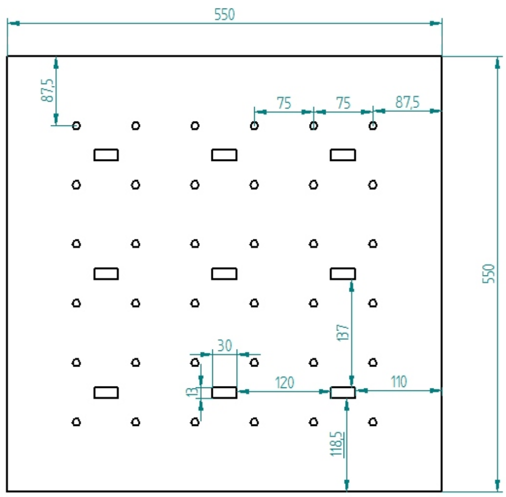

Figure 8 – Table top layout and drillings.

D. Electronic Schematics

Figure 9 presents the overall electronic schematics.

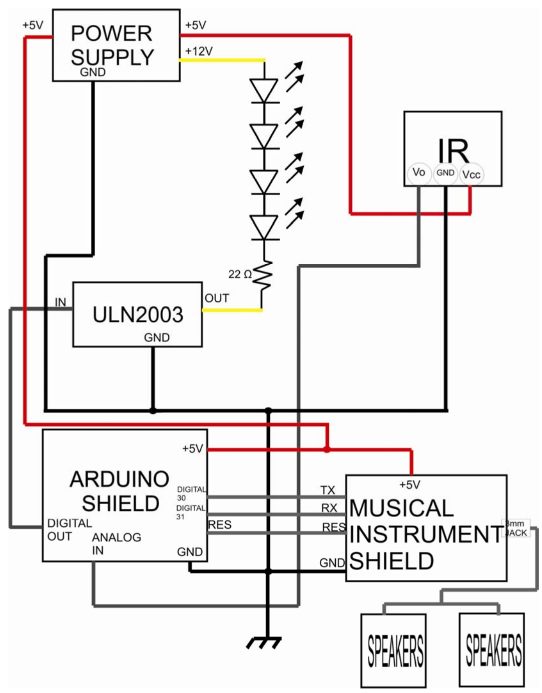

Figure 9 – Electronic schematics.

There are nine interactive blocks of four LED and one IR sensor. In each block the four LED are connected to an output of the ULN2003 (high voltage and high current Darlington transistor array) circuit for protection and current drive. A total of two ULN2003 circuits are used. The Arduino uses nine digital outputs to control the nine LED blocks and nine analogue inputs to read the nine IR sensor outputs. Each LED block digital output connects to a ULN2003 input and each block IR sensor output connects to one Arduino analogue input. When an IR sensor detects movement, the four LED of the block light up. The Arduino TX and RX pins connect to two Music Instrument Shield digital pins, creating a “fake” serial software port for sending the “notes” to the Music Instrument Shield. The speakers are connected to the Music Instrument Shield so that, when notes are sent to Arduino, the speakers play the corresponding sound. The power supply provides 5 V to the IR sensors, 12 V to the LED circuit, 5 V to Arduino shield and 5 V to Music Instrument Shield.

V. Implementation and Testing

This section describes the implementation process and the main tests performed and their results. The development process involved the selection, acquisition and assembling of the components, followed by programming, testing and debugging stages. Figure 10 depicts the prototype.

Figure 10 – Interactive table prototype.

Figure 11 presents the working principle of the table where the IR sensors measure the distance between table and obstacle (*e.g.* user hand). This input activates the corresponding block and controls the LED brightness and the sound volume.

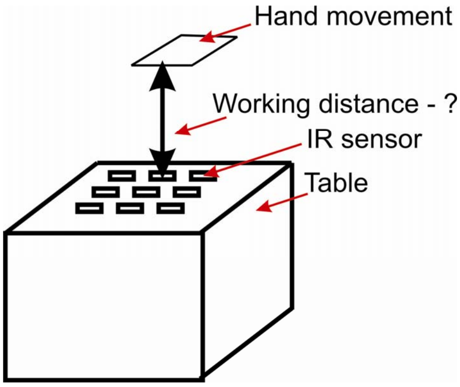

Figure 11 – Test setup.

Although the expected vertical working range above the table top was between 10 cm and 80 cm, the tests showed that in fact it had a vertical range between 1 cm and 60 cm. Thus, the resulting user interaction volume has a length of 55 cm, a width of 55 cm and a height of 59 cm.

VI. Future Developments

The system is trendy, attractive and new uses, apart from children sensory stimuli and exploitation, are yet to be discovered. As a result, the system is expected to evolve due to: (*i*) design changes, *e.g.*, inclusion of new features and technologies such as video and image, remote control (sound volume, LED colour, music or video), increased resolution (number of LED and IR sensor range) or additional sensors; (*ii*) personalisation, *e.g.*, adoption of different LED colours, music and support tables; (*iii*) reconfiguration, *e.g.*, allow people to upload their own music, videos or pictures.

The ultimate goal is to take the user into a new world through an interactive image, sound and light immersive experience.

Conclusions

This project was developed by a team of four third year students from diverse engineering and cultural backgrounds during the spring semester of 2012. The team was able to overcome all problems such as, e.g., the electronic assembly and the control programming tasks since no member had relevant background knowledge in electronics or computing. The supervision and brainstorming meetings, the emphasis on teamwork, on autonomy and the adopted methodology led to the project success. In the end, the team was able to provide the customer with a prototype complying with the initial requirements. The prototype is on display at ISEP museum for visitor interaction.

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