The PRISMA: A Visual Feedback Display for Learning Scenarios †

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Abstract: Ambient displays can play an important role in the teaching process guiding students to perform learning activities in public spaces. In the last years, automated feedback is becoming popular due to the proliferation of sensors, actuators, mobile devices, and networks. The contribution of this paper is twofold: (1) first, we present the implementation of an ambient display designed to provide feedback in learning scenarios using different actuators; (2) second, we present the results of a survey to investigate how adequate might be Bluetooth technology to sense and attract students to perform a learning activity.

Keywords: ambient display; ubiquitous learning; feedback; IoT; sensors; Bluetooth; Arduino

1. Introduction

Computers in 21st century should be the next technology becoming an integral, invisible part of people's lives [1]. In Mark Weiser's perspective, computers would be seamlessly integrated in our life, accessible and connected via networks or somewhere around us imbedded in walls, chairs, clothing, light switches, cars, in everything [1]. Inspired by this vision, Wisneski et al. [2] introduced ambient displays in the context of ubiquitous computing as a new approach interfacing people with online digital information moved off the screen into the physical environment, manifesting itself as subtle changes in form, movement, sound, color, smell, temperature, or light. Instead of demanding attention, the approach exploits the human peripheral perception capabilities. The displays situated and interacting in the close proximity are an addition to existing personal interfaces in the foreground, while the user attention can always move from one to the other and back [3].

An *ambient learning display* is defined as a beacon reporting changes of the learning context seamlessly integrated in the environment of the user [3,4]. Ambient learning displays can play an important role in the teaching process. Poor interaction or feedback can lead to inefficient learning performance in the classroom. For example, if a group of students talk so loudly that other students cannot concentrate, teachers have to stop and recall their attention leading to disruptive lectures. Automated feedback in classrooms using sensors is becoming popular due to the proliferation of mobile devices, the Internet of Things (IoT) paradigm, and Internet networks. Ham & Midden [5] argues that ambient persuasive technology is more effective than feedback demanding direct attention.

Based on these arguments, the contribution of the current paper is twofold: (1) an ambient learning display to provide feedback in classrooms, supporting students/teachers to study/teach

more efficiently is presented; (2) an informal learning scenario is investigated to identify the best setup to attract the attention of the student using an ambient learning display.

The PRISMA: An Ambient Learning Display

The PRISMA presented in this paper is an evolution of the Feedback Cube [6] which combined motion sensors (accelerometer, gyroscope and hall sensor), visual (LED ring) and auditory (piezo buzzer) actuators, as well as wireless communication capabilities in a cubic layout. A bottom-up approach is the piecing together of systems to give rise to more complex systems, thus making the original systems sub-systems of the emergent system. The PRISMA presented in this manuscript improves the Feedback Cube assembling the following new components (See Figure 1):

- 1 × Arduino Uno WiFi Rev2. The Arduino Uno WiFi Rev2 is an Arduino Uno with an integrated WiFi module. The board is based on the Microchip MEGA4809 with an ESP32 u-blox NINA-W13 WiFi Module integrated. The NINA-W13 Module is a self contained SoC with integrated TCP/IP protocol stack that can give access to your WiFi network.
- 1 × 8 × 8 LED Matrix (See left side of Figure 1). A LED matrix or LED display is a large, low-resolution form of dot-matrix display, useful both for industrial and commercial information displays as well as for hobbyist human–machine interfaces. It consists of a 2-D diode matrix with their cathodes joined in rows and their anodes joined in columns (or vice versa). By controlling the flow of electricity through each row and column pair it is possible to control each LED individually. By multiplexing, scanning across rows, quickly flashing the LEDs on and off, it is possible to create characters or pictures to display information to the user
- 2 × 8-bit shift registers. The LED matrix takes up 16 pins to control all LEDs, while there are less than 16 available pins on the board. In order to reduce the needed pins, the 8-Bit shift register SN74HC595N was introduced.
- 1 × Liquid Crystal Display (See left side of Figure 1). The LCD ST7565 can display pixels, not just text. This type of LCD in particular has 128 × 64 pixels, which appear dark gray on a green-blue background. It has a backlight but can also be used without the light on for daytime visibility
- 1 × Voltage Level Shifter. Because the working voltage level of the LCD ST7565 is 3.3V and the output voltage level of the Arduino is 5V, one voltage level shifter such as CD4050BE is necessary.
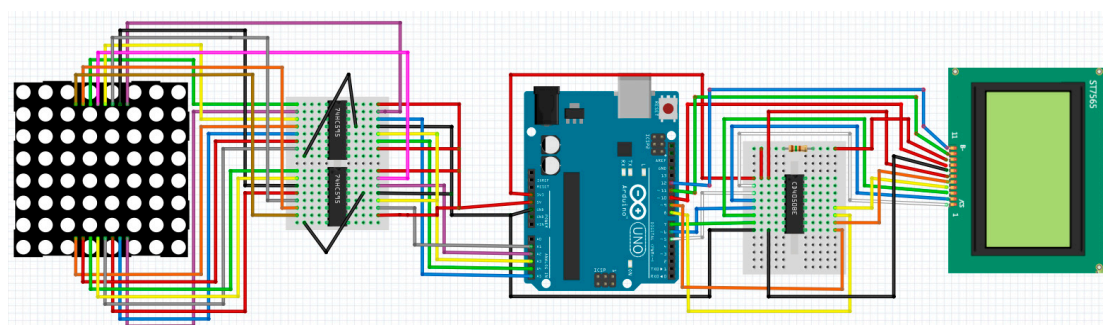
Figure 1. Components.

The sides of the PRISMA were designed in three different plexiglass-plastic materials to customize the exterior with three different levels of transparency (i.e., opaque, semi-transparent and transparent). Accordingly the sides of the PRISMA were made from black, white, and transparent Plexiglas. The interior of the PRISMA comprises a set of various sensor, actuator, and communication components as well as the necessary hardware to operate them (Figure 1). The dimensions of the PRISMA are 150 × 150 × 200 mm, so that all components fit in, while still ensuring a reasonable size for tangible interaction (See Figure 2).

The hardware operating the prototypes is based on the open-source electronics platform Arduino that runs a web server. An API was developed to enable most functions of the PRISMA via HTTP requests (Appendix A). The PRISMA can provide customized feedback using its actuators based on the information provided by sensors using 2 different channels: (1) HTTP requests via the API; (2) sensors connected to the Arduino (e.g., proximity sensor i.e., infrared or Bluetooth, temperature, humidity, etc.).

Bluetooth Low Energy (BLE) beacons are being novelty used to provide proximity-adapted feedback [7,8] in the field of shopping, access control, and home entertainment. Hereby, we investigate (Research Question) whether Bluetooth enabled mobile devices are a suitable channel to attract the attention from spontaneous learners, and to provide them customized feedback as they are approaching or moving away from a beacon (installed within the PRISMA).

2. Method

The Proximity Layered Feedback (PLF) model describes what kind of feedback services are more suited based on the proximity of the user to the feedback source [8] in the context of a smart learning environment (SLE). SLEs can be characterized by the following actions [9]:

(1) sense the students' actions and their current context;
(2) analyze the gathered data to identify their individual context; and
(3) react accordingly to offer adapted learning opportunities.

This research follows this approach to explore how an ambient learning display (i.e., PRISMA. See Figure 2) can sense students' proximity, and attract them to initiate a learning activity in a museum.

Figure 2. PRISMA.

2.1. Participants

A total of 35 persons participated in the study, thereof 25 (71%) were men and 10 (29%) were women. All participants were students.

2.2. Procedure

This study was performed next to the *Informática Vintage* museum installed in the hall of the main entry of the Information Systems Faculty in May 2019 (Figure 3). An observer sitting on a bench annotated students' behavior walking next to the museum. As they finished walking through the hall, they were invited to voluntary answer some questions in a face-to-face interview. The answers were collected using a mobile device.

Figure 3. Informática Vintage Museum (ETSISI – UPM).

3. Results

The following questions aimed to investigate students' behavior as they walk next to the museum getting in and out of the building.

The first question (Q1) explored whether students use their mobile device as they walk next to the museum so they might be lead to initiate a learning activity within the museum. The idea would be showing an alert in their mobile device (e.g., visual notification, acoustic signal, or vibration). Hence, the observer annotated whether students were watching their mobile device as they walked along the hall. The results show that most of the students (57%) were watching their mobile device or had it in their hands (Table 1). Contrary, only 43% did not have their mobile at hand.

The second question explored whether students stopped and watched the museum as they walk along the hall. The results presented in Table 1 show that only 2 (6%) students stopped to watch the museum. These numbers represent a base measure to contrast when a treatment to attract their attention is performed.

Table 1. Observations. Students' behavior walking next to the museum.

Q1	Is he/she watching his/her mobile?	%	n
	Never	43%	4
	Whole time	24%	8
	In some moment	21%	7
	No, but he/had the mobile in his/her hand	12%	4
Q2	**Stops and watches at the museum?**	**%**	**n**
	No	94%	33
	Yes	6%	2

As students passed next to the bench where the observer was sitting, they were invited to anonymously participate in a short survey (See Table 2). A sweet remunerated their participation. Q3 investigated what operating system do students use in their mobile devices. The results show that 62% of the participants reported they had an Android mobile device, whereas 38% had an iPhone.

Bluetooth Low Energy (BLE) beacons are increasingly used to identify users and their distance (proximity) to the beacon whenever the users have their Bluetooth enabled in the mobile device[8]. Hence, in Q4 we investigated the suitability of BLE technology to obtain the proximity of the students to the museum depending on whether they have their Bluetooth enabled or not. The results show that the majority of the participants (56%) had their mobile Bluetooth disabled. Participants with their Bluetooth enabled (44%) were asked to justify the reason. There were three different

causes: (1) they were using airpods; (2) they were using a bracelet to measure their physical activity; (3) their mobile activated the Bluetooth by default.

In the last question we wanted to explore to which extent students see a connection between what they study in the classroom, and what they see in the museum. 43% of the student did not see any connection between them.

Table 2. Questions of the interview.

Q3	Which mobile do you have?	%	n
	Android	62%	21
	iPhone	38%	13
	Other	0%	0
Q4	Do you have your mobile Bluetooth ON or OFF?	%	n
	OFF	56%	19
	ON	44%	15
Q5	Did you ever stop once at the museum?		
	Yes	80%	28
	No	20%	7
Q6	Do you see any connection between the content of the museum and what you study in the classroom?		
	Yes	54%	19
	No	43%	15
	Somehow	3%	1

4. Discussion & Conclusions

Evolving previous research on ambient displays for learning scenarios [3–8], this work has presented the implementation of the PRISMA, an IoT tool equipped with 3 different visual actuators (See Figure 4):

(1) The ring contains 24 individually addressable LEDs arranged in a closely spaced circle that can all be controlled via HTTP. The ring can display the full RGB color space with 16,777,216 colors at 256 brightness levels and perform the effects listed in Appendix A.
(2) The 8 × 8 matrix has been programmed to display alphanumeric values, words, and the effects listed in Appendix A.
(3) The LCD was programmed to display larger text and the effects described in Appendix A.
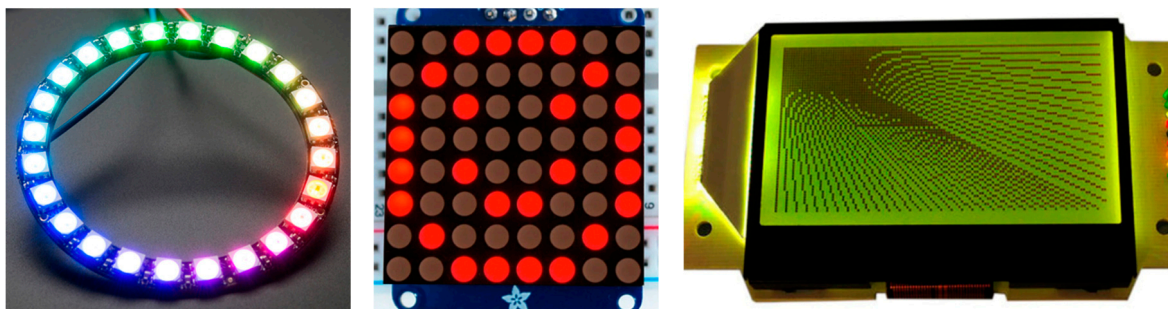
Figure 4. Visual actuators included in the PRISMA.

The PRISMA can support teachers and students in the following contexts:

- Presence control in classrooms. Using Bluetooth technology, the PRISMA might be programmed to count, register and display the number of students participating in every lecture.

- Personal response system in classrooms. Whenever the teacher might formulate a question with three different possible answers, the students might vote using their mobile device, and the PRISMA would provide feedback based on the responses.
- Noise (and ambient) control in classrooms. The PRISMA was developed to display colors (e.g., ranging from green to red) in real time based on the values reported by any wireless or wired sensor (decibels, temperature, light, humidity, pollution). This feedback might be very valuable to obtain the best learning conditions.
- Attract users to initiate a learning activity. The PRISMA can be programmed to provide a different visual effect based on the proximity of the user using beacons or infrared sensors.

The study presented in Sections 2 and 3 aimed to investigate how to attract students to examine a museum recently installed in the campus of the university. Hence, we investigated how suited could be Bluetooth technology to sense the students' presence, analyze their proximity, and react accordingly to offer adapted learning opportunities [9]. The results of the survey show that BLE technology is probably not the best choice since the majority of the students (56%) did not have the Bluetooth spontaneously activated. In further research, we will investigate infrared sensors to sense students proximity.

Nonetheless, the majority of the students (79%) were watching at their mobile device (or had it in their hands) when they walked next to the museum. These results provide evidence of the suitability of using personal mobile devices to attract users to enjoy available learning opportunities around them in the physical world.

The results of this study show that students do not fully exploit the learning opportunities available in public spaces. These conclusions rekindle the need to connect learning across formal and informal spaces, especially in schools and universities.

Appendix A

This appendix describes the functions featured by the PRISMA. Here is a link to a full demo: [https://vimeo.com/370971591]. The links below illustrate videos describing its behavior.

Method	Path	Function Description
24 RGB LED ring		
PUT	/ring/on/	Turns the LED strip on
Video:	https://vimeo.com/122884537	
PUT	/ring/off/	Turns the LED strip off
Video:	https://vimeo.com/122884536	
PUT	/ring/fade/	Color starts fading. The fading parameters (number, delay) are provided as a JSON object:
Video:	Fade slow five times: https://vimeo.com/122884370	{"n": x,"d": x}
Video:	Fade fast ten times: https://vimeo.com/122884369	
PUT	/ring/rainbow/	Starts a color rainbow
Video:	https://vimeo.com/122884367	
PUT	/ring/rainbow/circle/	Starts a color rainbow cycle
PUT	/ring/color/	Changes the color of the LED strip. The color values (red, green, blue) are provided as a JSON object:
Video:	https://vimeo.com/122884368	{"r": x,"g": x,"b": x}
PUT	/ring/pixel/	Changes the color of a LED pixel. The pixel values (number, red, green, blue) are provided as a JSON object: {"n": x,"r": x,"g": x, "b":x}
PUT	/ring/pixel/range/	Changes the color of a LED pixel range. The pixel values (number1,

		number2, red, green, blue) are provided as a JSON object: {"n1": x, "n2":x,"r": x,"g": x, "b":x}
8 × 8 LED matrix		
PUT	/matrix/stack/	Matrix lights the number of leds specified as param stacked from the bottom to the upper part. As it is a 8 × 8 matrix, if the param would be 16, the matrix would light the 16 bottom lights of the matrix, i.e., the bottom two rights of leads. 0 means no lights. 64 means all lights. The param is provided in a JSON object: {"stack": x}. Params JSON:
		• stack. integer number. range 0..64
Video:	https://vimeo.com/341059801	
PUT	/matrix/double/	Displays a double number with one unit digit and one decimal one decimal separated with dot. e.g., 0.1; 4.2; 9.9. The range of possible number to display with this function is from 0.0 to 9.9 The text is presented still (not moving). The param is provided in a JSON object: {"int": x,"dec": y}. Params JSON:
		• int(dou_int). integer number. range 0..9
		• dec(dou_dec). integer number matching the decimal part of the number. range 0..9
PUT	/matrix/integer/	Displays an integer number ranging from 0 to 99. The text is presented still (not moving). The param is provided in a JSON obeject: {"int": x}. Params JSON:
Video:	https://vimeo.com/341059693	• int(number). integer number. range 0..99
PUT	/matrix/level/	Displays a text in the matrix depending on the constants defined in configuration file in levels 1 to 5. e.g., 1) Very bad, 2) Bad, 3) Neutral, 4) Good, 5) Very good. The text is presented moving from right to left in a specific speed. The params are provided in a JSON object: {"level": x,"speed": y}. Params JSON:
		• level. integer number. range 1..5. Keys in configuration file: 1(xxxx); 2(xxxx); 3(xxxx); 4(xxxx); 5(xxxx);
		• speed. integer number. rang 0..5. Whereas "0" is no movement;
Video:	https://vimeo.com/341059719	"1" is the slowest speed; "5" is the fastest speed.
PUT	/matrix/text/	Displays a text in the matrix based on the params provides. The text is presented moving from right to left in a specific speed. The params are provided in a JSON object: {"text": x,"speed": y}. Params JSON:
		• text. String text max 30 chars. e.g., "Hello World!"
		• speed. integer number. rang 0.5. Whereas "0" is no movement;
Video:	https://vimeo.com/341059880	"1" is the slowest speed; "5" is the fastest speed.
Liquid Crystal Display		
PUT	/display/buffer/	Display the text in the buffer. Parameter(s): None
PUT	/display/clear/	Clear the buffer. Parameter(s): None
PUT	/backlight/color	Colors the backlight of the display. Values range from 0 to 3 meaning: 0 backlight OFF; 1 red light ON; 2 green light ON; 3 blue light ON. Params URL:
Video:	https://vimeo.com/341059595	• int(color). integer number. range 0..3
PUT	/display/fadeToBlack/	Displays n chars specified as parameter. The chars are presented from top left to bottom right. The display is 8 rows X 21 cols, i.e., 168 chars capacity. e.g., if "num" is 42, and char is "*", the display shows 42 asterisks ("****** ...*****") in the top 2 rows. The params are provided in a JSON object: {"char": x,"num": y}.Params JSON:
		• char(character). alphanumeric or any character
		• num. integer number. rang 0.168. Whereas "0" is no chars

Video:	https://vimeo.com/341059574	presented.
PUT	/display/writeLine/	Display a text in the position (x, y). The params are provided in a JSON object: {"x": x,"y": y,"text": this is a text}. Parameter(s):
		• x: the x coordinate of the beginning point.
		• y: the y coordinate of the beginning point.
Video:	https://vimeo.com/341059925	• text: the text to be displayed.

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