Electroluminescent based Flexible Screen for Interaction with Smart Objects and Environment

Orkhan Amiraslanov
German Research Center for artificial Intelligence
Trippstadter str. 122, D-67663, Kaiserslautern, Germany
Orkhan.Amiraslanov@dfki.de

Jingyuan Cheng
German Research Center for artificial Intelligence
Trippstadter str. 122, D-67663, Kaiserslautern, Germany
jingyuan.cheng@dfki.de

Peter Chabrecek
SEFAR AG
Töberstr. 4, CH-9425, Thal, Switzerland
Peter.Chabrecek@sefar.ch

Paul Lukowicz
German Research Center for artificial Intelligence
Trippstadter str. 122, D-67663, Kaiserslautern, Germany
paul.lukowicz@dfki.de

ABSTRACT
In this paper we propose an adjustable structure for flexible screens, based on electroluminescent phenomenon. The final product is thin, flat, flexible, long-lasting, easy to modify, reproduce and install. When combined with pressure matrix, it could become a touchscreen. Changeable pixel number and pixel size, plus the flatness and flexibility, make this structure ideal for interaction interface prototype for smart objects, where the surface size, shape and flatness are the main requirements. As demonstration we show this flexible screen on a window, on a bottle and on a gymnastics mat.

Author Keywords
Flexible screen, electroluminescent, interaction with smart objects.

ACM Classification Keywords
B.1.1 Hardware: Control structures and microprogramming

Control Design Styles: Hardwired Control

General Terms
Design, Verification.

INTRODUCTION
Visual interface demonstrates a very important role in human-machine and human-environment interactions. Nowadays, most of the screens however, are square-shaped and rigid, which limits their applicability in wearable and ubiquitous screen applications. When a soft surface with irregular contours, shapes and even thickness are the case (e.g. a pant or a spherical surface), then current commercially available screens are not able to fulfill the requirements. In this paper we focus on providing an easy prototyping method to equip unusually shaped surfaces with the flexible screen which fits perfectly in such applications. Although either used hardware structure (column and row scanning, details in section "System Structure") and the material (electroluminescent or light emitting capacitor) are not completely new, the combination of them makes the following contributions:

1. Easy prototyping: the screen is made by cutting the raw material and sticking uncoated electrodes along the rows. The control circuit design was implemented on a breadboard for ease of prototyping and design is ready to be implemented on a printed circuit board(PCB). Both pixel number and pixel size also the shape can manually be picked and chosen, while no special equipment other than soldering iron is required.

2. More natural surface, foldable and easy to install: the screen is flat and flexible in 2 dimensions. It can be rolled up before installing (e.g. for the wall out side of a building, the whole screen can be dropped from ceiling or window and spread out naturally through gravity, without any external scaffolding as when installing rigid display) or rolled up and carried easily before/after usage (e.g. gymnastic mat). The material is durable enough to withstand severe weather conditions.

3. Possible to become a touch-screen: combined with another layer of flexible resistive matrix [9], as a further implementation, we are planning to make a single layer of flexible touch screen.

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We would like to emphasize that, neither we plan to compete with commercial devices, nor we want to develop new electroluminescent material from scratch. The novelty of this work lies in combination, that we provide a method for quick prototyping a flexible screen in laboratory. The surface size can be either small or big with small or big pixel sizes, can be set to any shape, thus making it useful for human-environment and human-smart object interaction (e.g. a room where walls, cabinets, windows, tables and chairs, cups and etc. are all covered seamlessly with this screen. Examples are shown in Fig. 2, 3 and 4).

Related work

Looking into flexible screen solutions in the market, the most anticipated invention could be Youm: a rollable display for Samsung mobile [8], which will be released shortly. Such screen counts back to 2006, when Philips showed an OLED prototype. The application of these screens varies from small area as wrist display for smart watch, curved smartphone screen to big area as TV. We probably can expect buying such OEM screens with selectable size in the near future. However, having it in user-designed shapes (e.g. a spherical) and sizes are still infeasible. The other solution is LED displays, both as commercial available device for out-door advertisement or as small grids on chest [6] or as wrist worn display [4]. The benefit of LED display lies in its low cost and scalability. However, for large area, the amount of LEDs must be increased or an external layer has to be laid above to spread light from on a single LED into a bigger area. For small area, the pixel number is then limited by the smallest LED size (∼ mm level). The height of single LED also makes a flat surface not straightforward (still possible, when embedded in a layer of transparent plastic). Additional work has been done on developing new material for flexible, elastic display [3], [1]. There are enough work on driving matrix structured displays, e.g. [5], [7], just to name a few.

SYSTEM STRUCTURE

The hardware structure of our system is given in Fig. 1. The whole display is composed of $n \times m$ electroluminescent plates plus n vertical drive lines and m horizontal drive lines. When one vertical line and one horizontal line are enabled and the rest are disabled, the electroluminescent plate at the crossing point is selected and lit up. By scanning trough all the vertical and horizontal lines at a speed quick enough (in this case, higher than 10Hz for human eyes), we form up an image on the screen. The whole circuit decoupled into two parts: high voltage AC part (current flow that provides energy for lighting up pixels) and low voltage DC part (driving circuitry with microcontroller). With a DC-AC inverter the required high AC voltage to drive the flexible display can come from a low-voltage battery pack, which means the whole system is portable (no need for getting energy from commercial power line).

The Electroluminescent (a.k.a. a Light-Emitting Capacitor, or LEC) panels are widely used in the industry to make background lights for LCD displays and as night lights. The panel is a capacitor where phosphor plays a role as dielectric and its sandwiched between the conductive plates. The light emission occurs only when high frequency($\sim 1KHz$) alternating

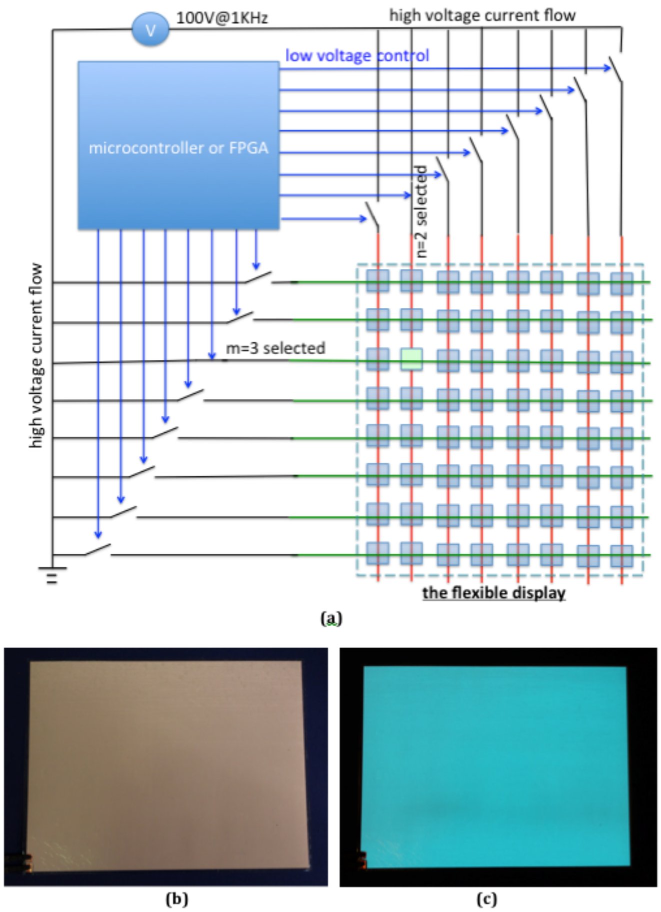

Figure 1. System structure: (a) blog diagram where pixel(2,3) is selected, (b) unlighted raw material, (c) lighted raw material

current is applied. The material we are currently using is designed by SEFAR AG, which should be driven by AC voltage of $100 \sim 110\ V, 400 \sim 1500\ Hz$. Overall lifetime of the material varies between $10.000 - 15.000$ hours. Depending on the brightness level and operating frequency. Moreover, it features very low power consumption ($0.1\,W$ for $1\,cm^2$ area), and can be easily bent and twisted without any damage. The brightness of the material can be adjusted either by changing the scan time or by adjusting input voltage of the inverter.

The structure we currently deployed is scalable, the control circuit grows with $n + m$ while the pixel number grows with $n \times m$. Pixel size for the complete matrix can vary depending on the required resolution. Practically, driving circuit can provide up to $150\ mA$ current for each pixel. In our case, the smallest pixel size that is manually possible to implement is $1 \times 1mm$, and it can be increased up to $30 \times 20cm$ depending on the resolution requirements.

In this paper we just demonstrate the idea with prototyping and we set the pixel number to be 8×8, which is already efficient to display a single letter, a digit or simple signs and the pixel size to $9 \times 9\ mm$. The limit on pixel number lies more in the electroluminescent material, which is lighted up only under certain voltage and frequency range. Also there exists "light leakage" from lighted pixel to the adjacent pixels. The current screens are all made manually, that is to say, the pixels are cut out by hand and the connected and wired by hand. Manufacturing the screen by machine lies in the capability of SEFAR AG and is our next research step. This could enable higher pixel numbers and better performance. Trying out other materials, e.g. FLATLITE from E-Lite Technologies [2], is also included in our future plans.

APPLICATION SCENARIOS

To demonstrate variety of possible applications of the flexible screen, below we show 3 basic scenarios:

1. On a bottle, where the surface is curved.
2. On a window, where weather information is provided while keeping see-through function still.
3. On sport mat, which can be used to give support trainees during an exercise and later easily be rolled up together with the mat without and damage.

On a curved surface

In Fig. 2 we display digits on a curved surface. For simplicity, natural digits $(0 - 9)$ are chosen. The purpose of this experiment was to print temperature of liquid inside of the bottle directly on its surface. To better demonstrate the possibility of equipping irregular surface, we light up the first roll at bottle neck, too. Further interesting information can include: liquid's chemical composition, brand name, important information on how to use the bottle's content etc. All the enumerated options are extra and can easily be done by upgrading the circuitry and adding special sensors. A video is available at `http://youtu.be/SVHoxsPJVKo` where we display digits. This scenario can be expanded to other containers with complex shapes (e.g. cup, bowl, kettle, flowerpot), complex surface (sofa chair, pillar, vacuum cleaner) and of course regular surfaces (e.g. desktop, cabinet, washing machine).

Weather on a window

In Fig. 3 we attach the screen to a glass window facing to street. We print symbols for two different weather information on it: cloudy or clear weather. Pixels are a bit shifted, so that user can read the screen plus have a transparent partial view of the outside. Some basic background information (e.g. outside temperature, ambient light level, humidity) can also be added easily.

Sport signs on a mat

With this application we want to support people when they are training on a sport mat, both the newbies who need technical direction on training routine or guideline on how to perform the activity correctly, and by continuously monitoring the trainees, training counts, goals and burned calories etc. data can be printed on the mat directly. Since the display is flat and foldable, it can be integrated into normal sport mat and later just be folded or rolled up. As a simple demo (Fig. 4) we print the signs of a person seated with arm raised up, standing straight and doing push-ups. A Further step would be to combine resistive pressure matrix and our flexible screen to

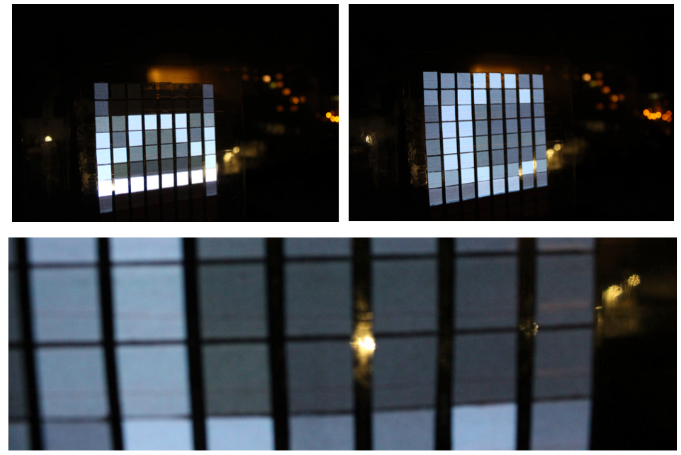

Figure 3. Weather information on a window: cloudy (cloud is displayed) and clear night (a crescent), and the streetlight visible between pixels

Figure 4. A sport mat with 3 posture signs: sitting, standing, doing push-ups

make a smart training mat which recognizes the sport activities and gives feedback to the user at the same time without any external disturbance.

Other possible scenarios

The advantage of our screen against others are the combination of flatness, flexibility, the area it can cover and cost of the material. Possible applications can be more:

1) Outside of the buildings: at night the wall of most of the buildings are dark or just partly lit up by some big screens. To display a big picture, which is visible from far-away, requires big area while the pixel resolution doesn't have to be very high. To give an example, all buildings around a square where a outdoor new year party is held, can be quickly covered up with such screens and uncover the next day. The rolled up screens can then be transported to somewhere else and re-used again.

2) As a window blind: thickness of the EL material allows to make window blinds which can print some information, such

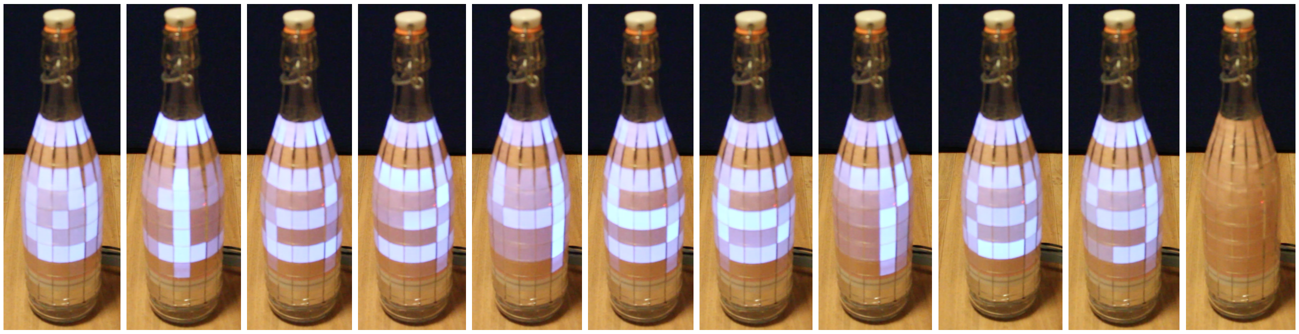

Figure 2. Digits $0 - 9$ are displayed on a bottle (plus off-state)

as clock, room temperature, humidity, etc. in forms of text and symbols.

3) For fans: nowadays fans of football or music stars carry with them glow stick, scarf, or portable LED displays to show their love and share their feelings. Our screen can be folded, carried in the pocket and later spread out, providing fans the possibility to express more. Similar application can be foreseen by parade, police evacuating people or demonstrations and so on.

CONCLUSION

We propose a combination of matrix driving circuit and electroluminescent material based screen, which enables easy prototyping of scalable and flexible display for interaction with smart environment and objects. We describe the hardware structure and discuss working principle of the screen comprehensibly. Three basic application scenarios are carried out to prove the idea of flexibility and to demonstrate the possibility of covering different areas of human surroundings with it, which hopefully will raise new interaction methods.

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