Dynamic Braille

The ability to read a full page of Braille text using refreshable displays would help people with visual impairments benefit from the growing advances in computer technology.

By Yoseph Bar-Cohen

Research with electroactive polymer (EAP) technology is giving hope to people with visual impairments around the world who someday may be able to read text on an inexpensive, full-page, refreshable Braille display.

The development of low-cost, efficient, refreshable displays for Braille text would give Braille readers access to state-of-the-art digital technology and the enormous volume of information on the Internet, opening doors for educational, employment, and recreational opportunities.

The World Health Organization estimates there are about 314 million visually impaired individuals globally, including 45 million who are blind. Many have been missing out on the computer revolution because they cannot access text-messaging, e-mail, and other technologies that use computer-controlled devices and electronic displays.

Although there are numerous challenges to devising low-cost mechanisms, materials, and processing techniques for a refreshable Braille display, advances in EAP technology may make those capabilities feasible in the not-too-distant future.

The new Center for Braille Innovation (CBI) at the Boston-based National Braille Press recently started collaborating with the EAP community to accelerate development of full-page Braille displays and bring their cost down significantly. Most commercially available Braille displays cost several thousand US dollars, according to Noel H. Runyan, a member of the CBI team.

Because of the unique possibilities that effective EAP materials can provide for the Braille-reading community, the broad topic of haptic/tactile interfaces will also be the focus of a special session 8 March, 2010 at the Electroactive Polymer Actuators and Devices (EAPAD) conference at SPIE Smart Structures and Materials+Nondestructive Evaluation and Health Monitoring.

Subhed: Challenge

Over the last few centuries, many tools have been developed to assist blind persons, including the writing code using raised dots known as Braille. (See Braille Development at right). It consists of rectangular shaped cells of raised dots arranged in column pairs.

Unlike visual perception of conventional text, Braille systems involve tactile perception and require developing the skill to read and decode the dots. Such tactile displays may include single character presentation devices, single line units, and full page presentation boards filled with characters.

Producing a full-page Braille display is difficult because it requires packing many small actuated dots into a small, closely-spaced arrangement without interferences. Specifically, the dot diameter should be about 1.5 mm, the raising height approximately 0.5 mm, and a desired actuation force of at least 0.15 N [Kato et al., 2007[1]; Matysek et al., 2009[2]].

A standard Braille page is 11" by 11.5" (28 cm × 30 cm) and has room for 25 lines of 40 characters per line, with each page totaling 6000 to 8000 dots. The small dimensions and the complexity of producing a reliable display that addresses the daily wear and tear pose great challenges for developers, and the small market for active displays makes the cost high. Constraining the active display to one cell would address the size issue. But the disadvantage is that the user's fingertip would not be able to dynamically sweep across the Braille characters, and relative movement is necessary for optimal tactile sensation and reading.

Commercial and reported prototypes of Braille displays are generally electro-mechanical devices that raise dots through holes in a flat surface. Over the years, various actuators and novel mechanisms were developed and tested using such actuation mechanisms as electromagnetic, piezoelectric, thermal, pneumatic, and shape memory alloys. Some, using piezoelectric stacks, have become available in commercial form, but most of them are limited to single characters and single line displays.

Subhed: Developers

Many EAP materials that have emerged in recent years, however, are making it increasingly feasible to pack many actuators in a small area without interferences, opening up enormous potential for the development of active, full-page Braille displays. Pioneering these efforts, the author conceived a refreshable Braille display in 1998 after he was inspired by people with vision impairments holding a convention at a Washington, DC, hotel where he was staying [Bar-Cohen, 1998[3]; Bar-Cohen, 2004[4]]. This concept uses an EAP actuator array made of a field-activated type material (see Figure 1). Rows of electrodes on the top surface and columns on the bottom of the EAP film allow activating individual elements in the array.

Each of the elements is mounted with a Braille dot and is lowered by applying a voltage across the thickness of the selected element.

Since 2003, other researchers have reported the development of EAP-based actuators:

- Carolina State University [di Spigna, et al., 2009[5]]
- Darmstadt University of Technology, Germany [Schlaak et al., 2005[6]; Matysek et al., 2009[2]]
- Penn State University [Ren et al., 2008[7]]
- SRI International [Heydt and Chhokar, 2003[8]] (See Figure 3)

- Sungkyunkwan University, South Korea [Choi et al., 2004 [9]; Lee et al., 2004 [10]; Choi et al., 2009 [11]] (See Figure 4)
- University of Tokyo, Tokyo, and the National Institute of Advanced Industrial Science and Technology (AIST), Osaka, Japan [Kato et al., 2007 [1]]
- University of Wollongong jointly with Quantum Technologies, Sydney, Australia [Spinks et al., 2003 [12], Ding et al., 2003a [13] and 2003b [14], Spinks and Truong, 2005 [15], Spinks and Wallace, 2009 [16]]

The developers used such materials as conducting polymers, dielectric elastomers, ferroelectric, ionic polymer-metal composite (IPMC) and polyvinylidene fluoride (PVDF) films. The focus of these efforts has been on developing miniature actuated small pins/dots that can be packed into a small area while generating sufficient displacement and force.

The EAP actuators that have been developed activate various mechanisms consisting of moving levers; rolled film over pre-strained spring; bimorph configuration; multi-layered array; and a diaphragm with spring-backed elements, taking advantage of the pre-strain. Examples of the developed devices are shown in

Figure 2 and

Figure 3.

While these recently developed displays are close to performing at the required specifications, there are still challenges that prevent them from becoming a commercial product. One is the need for low-activation voltage when using field-activated type EAP such as dielectric elastomers and ferroelectric EAP. It is desirable to reduce the voltage to a few hundred or less rather than the few thousand volts currently required for the field-activated, EAP-based devices. Other challenges include the insufficient force in the case of IPMC as well as the short cycling life of the conducting polymers. Also, there are issues related to their reliable operation and limitations in mass production.

Subhed: Other applications

EAP materials are being considered for use in many other applications beyond Braille displays, such as haptic and tactile interfaces/displays for interaction with and/or through computers. Employing EAP for such interfaces can contribute greatly to applications such as teleoperators and simulators, computer interfaces and video games (e.g., joysticks and Wii), robotics, touch screens, tactile displays, and surgical force-feedback devices. These applications represent an enormous market for the development of the required EAP actuators and can significantly help advance this field.

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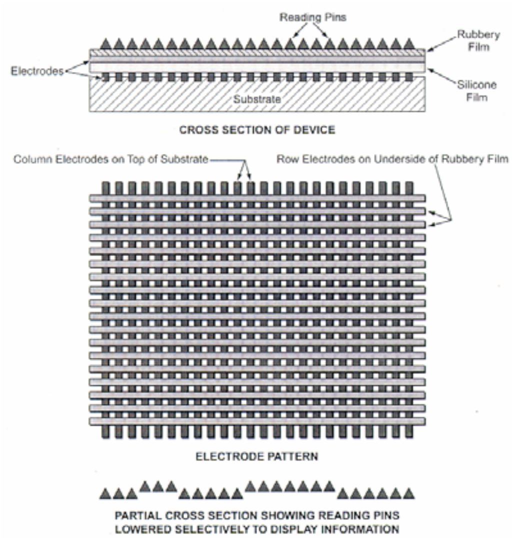

Figure 1: An EAP film with addressable dots at the intersection between selected row and column electrodes to which voltage is applied [Bar-Cohen, 2004 [4]].

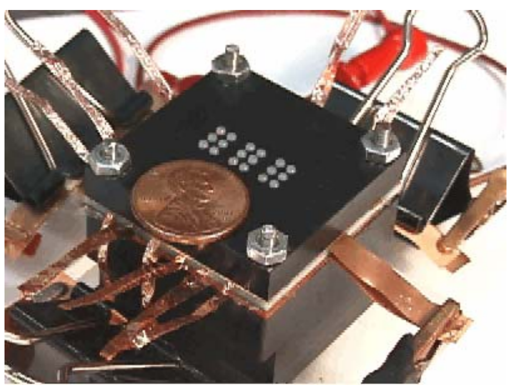

Figure 2: The prototype developed by scientists at SRI International uses an actuator array and dielectric elastomer diaphragm with thin metal traces that activate individual dots. It combines pressurized air and dots having diameter of 1.6 mm activated by 5.68 kV, producing displacement of 450 µm. Recently, they investigated enhancements of the design using thickness mode displacements, and they are considering presenting the results at the EAPAD conference in March 2010. (*Courtesy of Richard Heydt, SRI International, CA, [Heydt and Chhokar, 2003* [8]*] with permission of the Society for Information Display*.)

Figure 3: A refreshable Braille display developed at Sungkyunkwan University, South Korea, uses dielectric elastomer EAP with bubble shape dots. The prototype is shown being tested by a blind person in an overall view and a close up on the fingers (*Courtesy of H.R. Choi, Sungkyunkwan University, South Korea*.)

References (may run online only)

1 Y. Kato, et al. "Sheet-type Braille Displays by Integrating Organic Field-Effect Transistors and Polymeric Actuators," IEEE Transactions on Electron Devices, Vol. 54, No. 2, pp. 202–209, 2007.

2 M. Matysek, et al. "Tactile Display with Dielectric Multilayer Elastomer Actuators," Proc. of SPIE, EAPAD Conference, Vol. 7287, 72871D, 2009.

3 Y. Bar-Cohen. "Active Reading Display for Blind," New Technology Report, Item No. 0008b, Docket 20410, Feb. 5, 1998.

4 Y. Bar-Cohen, Ed. "Electroactive Polymer Actuators As Artificial Muscles—Reality, Potential and Challenges," 2nd Ed., SPIE Press, 2004.

5 N Di Spigna, et al. "Application of EAP materials toward a refreshable Braille display," Proc. of SPIE, Vol. 7287, 72871K 2009.

6 H.F. Schlaak, et al, "Novel multilayer electrostatic solid state actuators with elastic dielectric," Proc. of SPIE, Vol. 5759, 121, 2005.

7 K. Ren, et al. "A compact electroactive polymer actuator suitable for refreshable Braille display," Sensors and Actuators A: Physical, Vol. 143, No. 2, pp. 335–342, 2008.

8 R. Heydt and S. Chhokar. "Refreshable Braille Display Based on Electroactive Polymers," Proc. of the International Display Research Conference, Society of Information Display, Vol. P7.5, 2003.

9 H.R. Choi, et al. "Tactile Display as a Braille Display for the Visually Disabled," Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 1985–1990, 2004.

10 S. Lee, et al, "Braille display device using soft actuator," Proc. of SPIE EAPAD Conf., Vol. 5385, pp. 368-379, 2004.

11 H.R. Choi, et al. "A Braille Display System for the Visually Disabled Using Polymer Based Soft Actuator," Chapt. 23 in "Biomedical Applications of Electroactive Polymer Actuators, E. Smela and F. Carpi, Eds, 2009.

12 G. M. Spinks, et al. “Ionic liquids and polypyrrole helix tubes: bringing the electronic Braille screen closer to reality,” Proc. of SPIE EAPAD Conf., Vol. 5051, 372, 2003.

13 J. Ding, et al. “Use of Ionic Liquids as Electrolytes in Electromechanical Actuator Systems Based on Inherently Conducting Polymers.” *Chemistry of Materials,* Vol. 15, No. 12, pp. 2392-2398, 2003.

14 J. Ding, et al. “High Performance Conducting Polymer Actuators Utilising a Tubular Geometry and Helical Wire Interconnects,” *Synthetic Metals,* Vol. 138, pp. 391-398, 2003.

15 G.M. Spinks and V-T. Truong. “Work-per-cycle analysis for electromechanical actuators,” Journal of Sensors and Actuators A: Physical, Vol. 119, No. 2, pp. 455-461, 2005.

16 G.M. Spinks and G.G. Wallace. “Actuated Pins for Braille Displays,” Chapter 13 in “Biomedical Applications of Electroactive Polymer Actuators” E. Smela and F. Carpi, Eds, 2009.

17 N. Runyan, personal e-mail with the author, May 2009.

Sidebars:

170 words

Braille Development

Louis Braille developed the writing code that carries his name when he was only 15 by modifying the night-writing communication method developed by French Army Capt. Charles Barbier.

Barbier’s code, with 12 dots and dashes per alphabetical character, was intended to give soldiers the ability to communicate silently on the battlefield at night. However, it was rejected as too complicated, and he took his invention in 1819 to the Royal Institute for Blind Youth of Paris where Braille was a student. Braille took Barbier’s 12-dot code and reduced it to 6 dots per character, which he arranged in a rectangular shape along two columns of up to three dots each.

Braille’s innovation made the code much easier for fingertips to sense through touch and for significantly faster reading. In recent years, the Braille code was extended to 8 dots with two columns of four dots, increasing the possible combination of symbols from 64 to 256 and allowing representation of all printable American Standard Code for Information Interchange (ASCII) characters in a single cell.

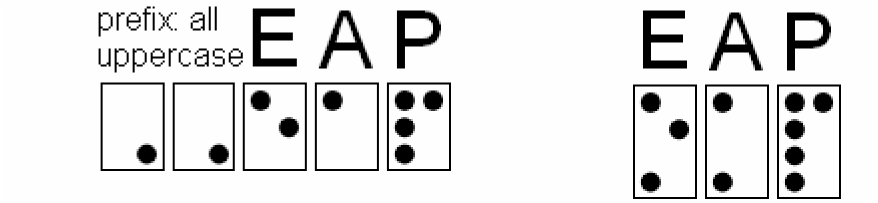

Figure 4: The acronym EAP in upper case is expressed in the 6-dot code based on Runyan[17], left, and the common English 8-dot Braille code system at right.

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Braille Innovations

The Center for Braille Innovation (CBI) is developing resources for the scientific community to facilitate development of low-cost electronic Braille display devices and the much-sought-after "Holy Braille" of a full-page Braille display.

Noel Runyan of Team CBI at the National Braille Press and founder of Personal Data Systems says the center is working on an actuator specification table for a Braille display that can serve as a tool for developers to define and document the key requirements of actuators for Braille and other tactile displays.

"Our CBI team is also developing Web pages that include a prior art listing of all known Braille display projects, at least those developments that got as far as patents, lab tests of hardware, or actual prototypes," Runyan says. "This should make it much easier to evaluate the potential of new technologies, in light of alternative approaches that failed or that turned into viable products."

Runyan's team is working with the EAP community and welcomes contributions from anyone who wants to take part. Contact him at Noel@PersonalDataSystems.com.