1-1-2009

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Hyouk Ryeol Choi
Sungkyunkwan University

Ducksang Kim
Sungkyunkwan University

Nguyen Huu Chuc
Sungkyunkwan University

Nguyen Huu Lam Vuong
Sungkyunkwan University

Jachoon Koo
Sungkyunkwan University

See next page for additional authors

Authors
Hyouk Ryeol Choi, Ducksang Kim, Nguyen Huu Chuc, Nguyen Huu Lam Vuong, Jachoon Koo, Jae-do Nam, and Youngkwan Lee

Development of Integrated Tactile Display Devices

Hyouk Ryeol Choi[a], Ducksang Kim[a], Nguyen Huu Chuc[a], Nguyen Huu Lam Vuong[a], Jachoon Koo[a], Jae-do Nam[b] and Youngkwan Lee[c]

[a] School of Mechanical Engineering, Sungkyunkwan University, Korea;
[b] Department of Polymer System Engineering, Sungkyunkwan University, Korea
[c] Department of Chemical Engineering, Sungkyunkwan University, Korea

ABSTRACT

As a major human sensory function, the implementation of the tactile sensation for the human-machine interface has been one of the core research interests for long time. In this research, tactile display devices based on dielectric elastomer are introduced among the works recently done by ourselves. Using dielectric elastomer for the construction of the tactile interface, it can provide stimulation on the human skin without any additional electromechanical transmission. Softness and flexibility of the device structure, ease of fabrication, possibility for miniaturization, and cost effectiveness are the representative benefits of the presented devices. Especially, the device application is open to a wide variety of purposes since the flexible structure offers excellent adaptability to any contour of the human body as well as the other objects. In this paper, the design of the interfaces is briefly explained and several examples of implementation are introduced.

Keywords: Tactile, Display, Sensing

1. INTRODUCTION

Tactile sensation is the most widely spread sensory function in the human body so that it is an essential part of the human perception mechanism. Complete or successful realization of the tactile function may place a cornerstone in the fields of robotics, virtual reality, medical engineering, etc. A tactile display is one of the most important communication devices and it conveys numerous information in the form of skin stimulation. Although the graphical or visual device has been a typical form of the modern information transferring tool, the role of the tactile display has been extended to various applications.[1–4]

In this research, several implementations of tactile interfaces are introduced such as dynamic Braille display, wearable tactile display, virtual keyboards which have been developed up to now in our group. Though there are variations in details, they employ dielectric elastomer for the basis of the tactile display and constructed with a notably simple mechanical and electrical architecture. The proposed devices are organized with a multiply layered array of tactile cells that generates vertical motion used to push up or down tactile stimulators. These electrically driven tactile stimulators can generate either small-scale vibratory motion or linear displacement. They differ from conventional devices in softness and controllable compliance, cost effectiveness, simple manufacturability, and high actuator density.

This chapter is organized as follows. In the sections 2 we briefly mention the basic principle and construction of the distributed actuation. In the following three sections, 3, 4 and 5, examples of tactile displays are included. Section 3 overviews the tactile display as a dynamic Braille display and Section 4 is about the wearable tactile display worn on the fingertip. Section 4 introduces the virtual keyboard with the wearable tactile display. Finally, the concept of integrated tactile display is briefly addressed with its technical perspectives in Section 5 and conclusions are given finally.

Further author information: (Send correspondence to Prof. Hyouk Ryeol Choi)
Hyouk Ryeol Choi: E-mail: hrchoi@me.skku.ac.kr

Electroactive Polymer Actuators and Devices (EAPAD) 2009, edited by Yoseph Bar-Cohen, Thomas Wallmersperger,
Proc. of SPIE Vol. 7287, 72871C · © 2009 SPIE · CCC code: 0277-786X/09/$18 · doi: 10.1117/12.816475

2. DESIGN OF TACTILE STIMULATOR

Depending on the design and fabrication technique, the dielectric elastomer actuator can be implemented in various forms and generate a wide range of motions from micro to macro scale. The tactile stimulator proposed in this research can provide durable and robust actuation since it is configured to generate mechanical output orthogonal to the surface of the elastomer film without employing the prestrain frequently used in the previous studies.[5] As shown in Figures 1, 2 and 3, this design provides relatively large orthogonal displacement compared to the size of the cell and allows very easy fabrication. The operating principles of the proposed tactile stimulator are described in details as follows. An incompressible thin circular elastomer film preshaped as a dome is attached inside a rigid cylindrical boundary frame. When a voltage is applied across the dielectric elastomer film, it is compressed along the axial (or thickness) direction, and thus, it expands along the radial direction. The expansion along the radial (or lateral) direction causes concave or convex bending of the elastomer (which may be called "buckling") and produces vertical displacement. The proposed design provides several advantages, which makes possible such as distributed actuation without any prestrain, ease of fabrication etc. Also, the proposed actuator can be extended to the other application and formulations in details with other related applications can be found in.[6,7]

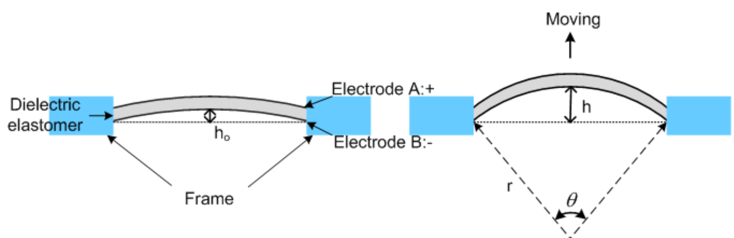

Figure 1. Working principle of tactile stimulator

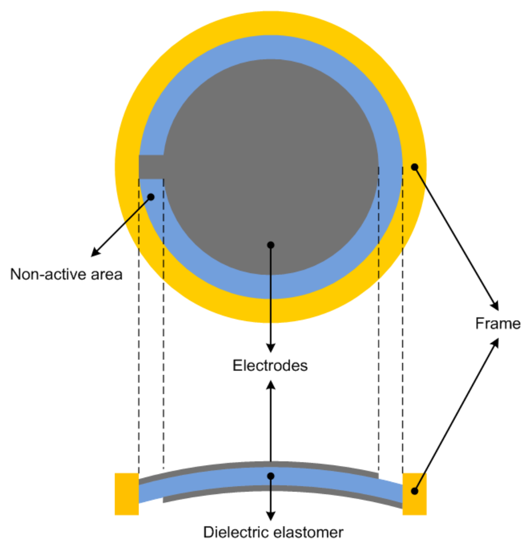

Figure 2. Construction of tactile stimulator

3. DYNAMIC BRAILLE DISPLAY

A Braille display adopting the proposed the tactile stimulator is overviewed in this section.[6,9] Construction of the actuator is explained as follows. A thin cylinderical polymer membrane like a coin is coated with conductive electrodes. Nominal thickness of the elastomer membrane is about 50 micrometer. In order to obtain large actuation force enough to be used for the tactile display, several laminated membrane actuators are stacked and

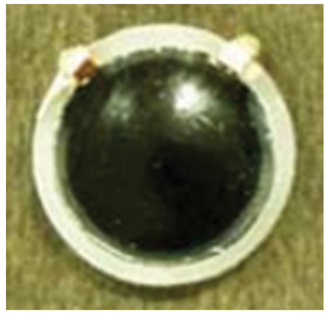

Figure 3. Tactile stimulator

combined with a rigid circumferential loop frame as shown in Figure. 2. The total thickness of the elastomer stack is about 750 micrometer. Note that the actual diameter of the elastomer stack is slightly larger than the rigid circumferential frame. Introduction of this oversized fitting design produces pre-deformation of a convex shape that guarantees unidirectional actuation mode. Here, the dielectric elastomer is not under prestrain, but just preshaped like a half sphere.

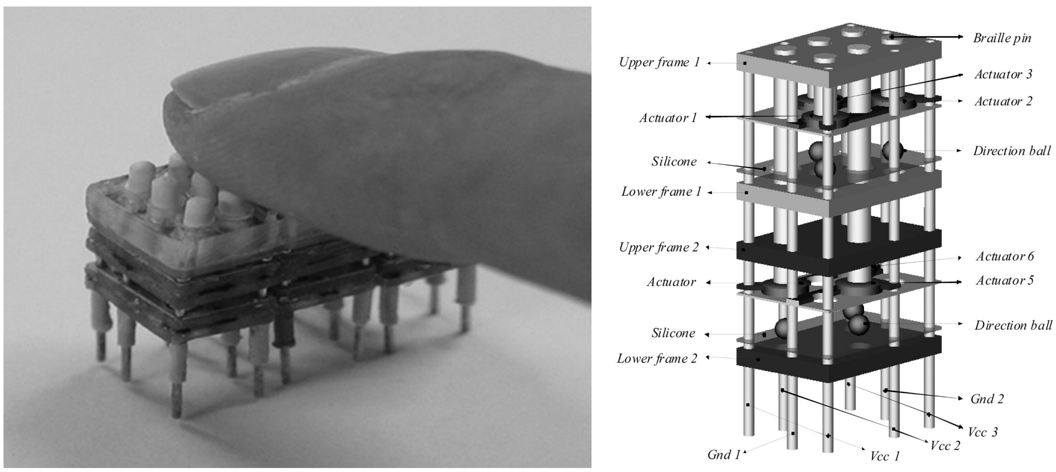

Figure 4. Dynamic Braille display and its design

A typical Braille display unit is constructed with six stimulating pins that are arranged in array format. An array normally represents a character as defined by the Braille alphabet. In the present work, a Braille display unit is constructed with the introduced tactile cells arranged in the format defined by the standard Braille display. The prototype and design concept are depicted in Figure 4.[9,10] Since each Braille cell is to be fully modularized for convenient installation, each unit can be plugged onto a circuit board with ease. With this simple drop-in feature, a number of Braille cells can easily be combined so that a Braille tablet may be manufactured by arranging multiple Braille cells in a matrix format as illustrated in Figure 5.

4. WEARABLE TACTILE DISPLAY

By extending the concept of the actuator described in Figures 1 and 2, we present a new type of a tactile display device that is wearable with multiple tactile stimulators embedded in a flexible polymer substrate as illustrated in Figure 6.[8] The device is actually a polymer sheet that has an embossed array of soft actuators. The polymer sheet is preformed with an embossed pattern in order to secure the moving direction of the actuator. The embossed pattern determines the direction of buckling, and thus, the arbitrariness of the direction of movement can be removed. As noted in Figure 6, the presented idea provides a number of benefits for the actuator construction, which are flexibility with comfortable softness, ease of fabrication, miniaturization, and

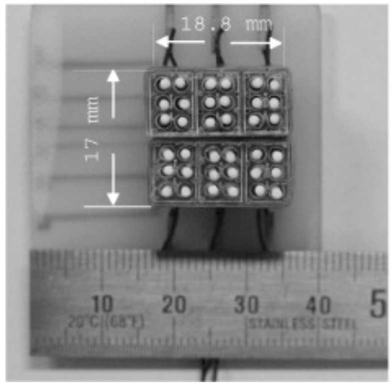

Figure 5. Braille tablet by assembling six modules of Braille cells

cost effectiveness. Attaining the flexibility, the device can be adapted to various geometric configurations and can be worn on any part of the human body, such as fingertip, palm, or arm or any curved surface.

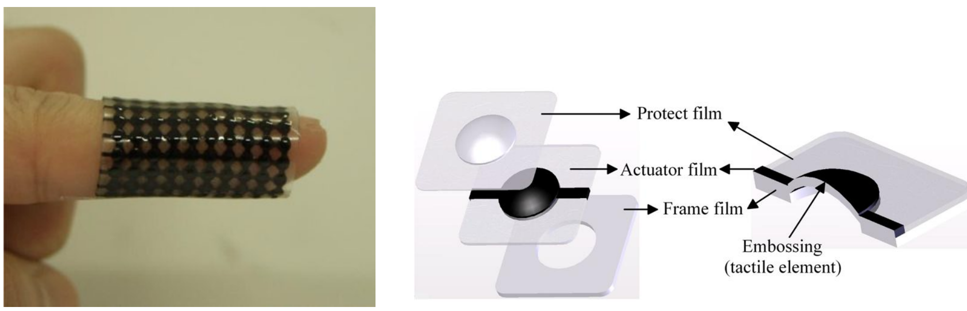

Figure 6. Wearable tactile display

Rolling up the presented actuator unit to a thimble shape tube, as shown in Figure 7, the device can easily fit on the human fingertip. The total active area for the device is 11×14 mm, and the centers of tactile stimulating elements are apart 3 mm, respectively. Each element is 2 mm in diameter and the initial convex height is 0.1 mm. The entire device is very flexible and light like a bandage enough to be worn at the fingertip.

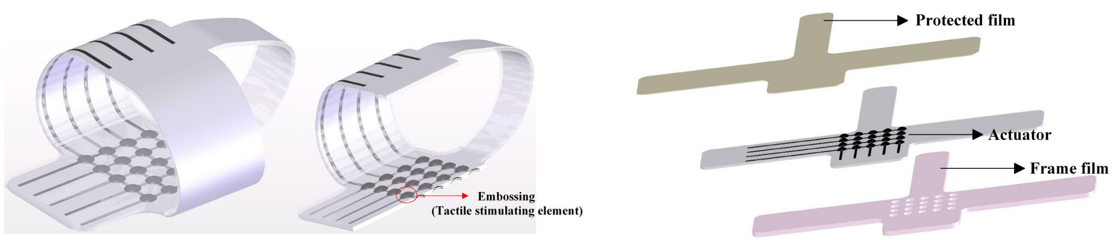

Figure 7. Fingertip tactile display

5. VIRTUAL KEYBOARD WITH TACTILE DISPLAY

Combining the proposed wearable fingertip tactile display with a virtual keyboard, a VRTD (Virtual Reality Tactile Display) system that transfers more realistic touch feel of keyboard to the user can be constructed. The compact version of the commercially available virtual keyboards provides the advantage of high mobility. However they sometimes cause confusion and discomfort of the users since the users have to hit the hard ground. By wearing the proposed tactile display device at the fingertips, the level of touch feel of keyboard can be significantly improved. As soon as the user hits a character, the tactile device will generate touch feel of keyboard. The proposed VRTD system configuration and concept are illustrated in Figures 8 and 9. A virtual keyboard (I-tech Co.) and a user interface (Visual studio.Net based on Windows XP) are used for controlling tactile display. Recognizing the working mechanism of the proposed VRTD, a visually impaired user also can benefit from the device. The device can deliver the input characters to the tip of finger if coded as the Braille rule so that the user can read out his input as soon as the characters are typed in.

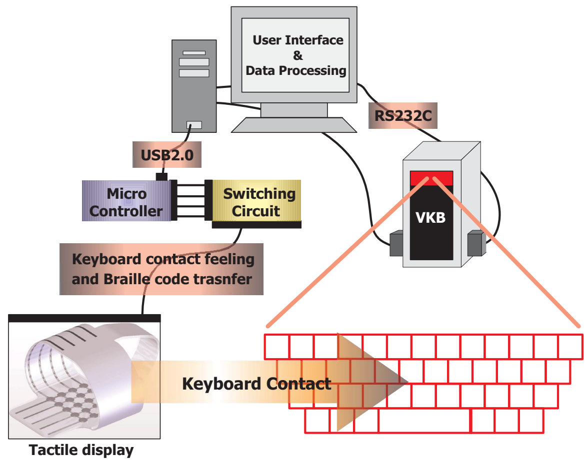

Figure 8. System layout of virtual keyboard with tactile display

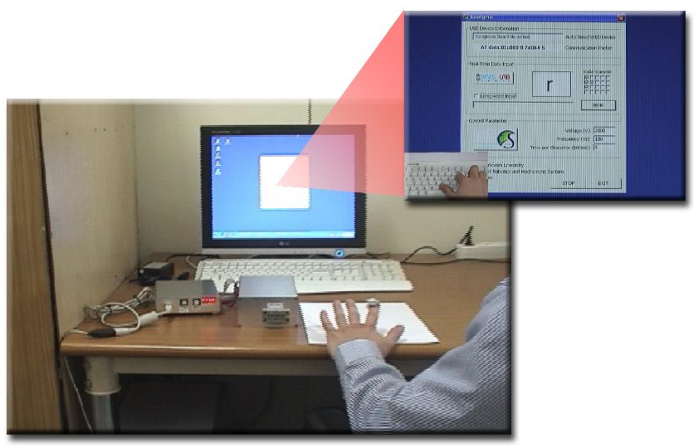

Figure 9. Experiments with virtual keyboard with tactile display

6. CONCLUDING REMARKS AND FUTURE PERSPECTIVES

In this paper, we introduced the applications of the dielectric elastomer actuator as a device for transferring the tactile feel with the developments of our groups, such as Braille display, wearable tactile display and virtual keyboard with tactile display. The details of each development can be found in the publications.[4,7–9,11,12] In addition, the recent investigations note that the dielectric elastomer can be utilized as an actuator as well as a sensor.[12,13] Integration of the tactile sensor and actuator helps us extend the aforementioned technology to new type of tactile interfaces and expect numerous applications in new areas such as games, automobiles, mobile devices etc. In those areas, the dielectric elastomer is very much attractive because its design and manufacturing can be simple and consistent, which results in cost effectiveness. Also, the same idea can be extended to the hybrid devices with ionic and non–ionic ElectroActive polymers.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Knowledge Economy (MKE) and Korea Industrial Technology Foundation (KOTEF) through the Human Resource Training Project for Strategic Technology.

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