Display of Virtual Braille Dots by Lateral Skin Deformation

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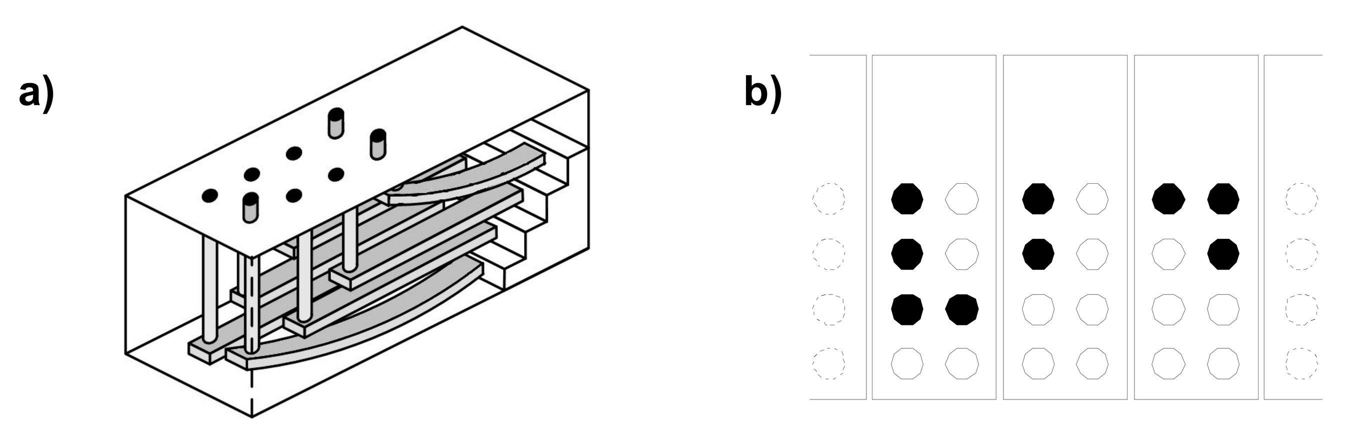
Introduction

Commercially available refreshable Braille displays have changed little in the past 25 years. Typical systems use cantilevered bimorph piezo-actuators (reeds) supporting vertical pins at their free end. Upon activation, a reed bends, lifting the pin upward. Braille characters are displayed by assembling six or eight of these mechanisms inside a package called a cell. While the elements of these cells are simple and inexpensive, the cost is driven by the necessity to replicate the cell 40 or 80 times to display a line of text.



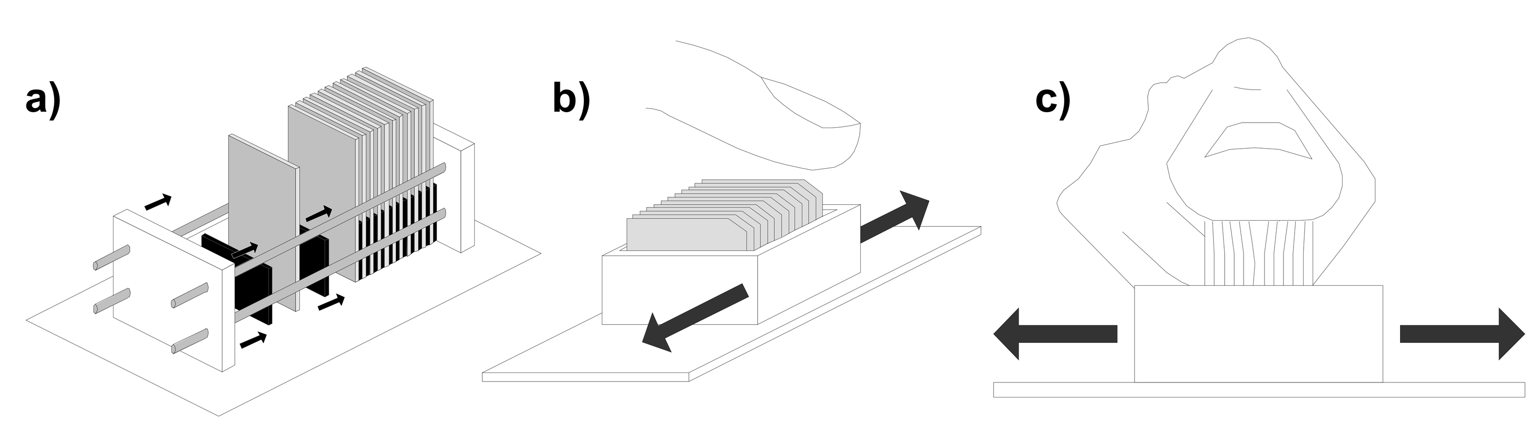
1. Conventional Braille display: a) cell actuation mechanism, b) array of cells.

The project described in this poster aims at creating a portable and low-cost alternative Braille display technology based on tactile illusions caused by lateral skin deformation. A pilot study was carried out to evaluate the feasibility of displaying a single line of Braille dots with a 1D STReSS-type tactile display (Pasquero and Hayward, 2003), called the Virtual Braille Display (VBD).

Virtual Braille Display

2. Virtual Braille Display: a) STReSS-type display, b) mounted on slider.

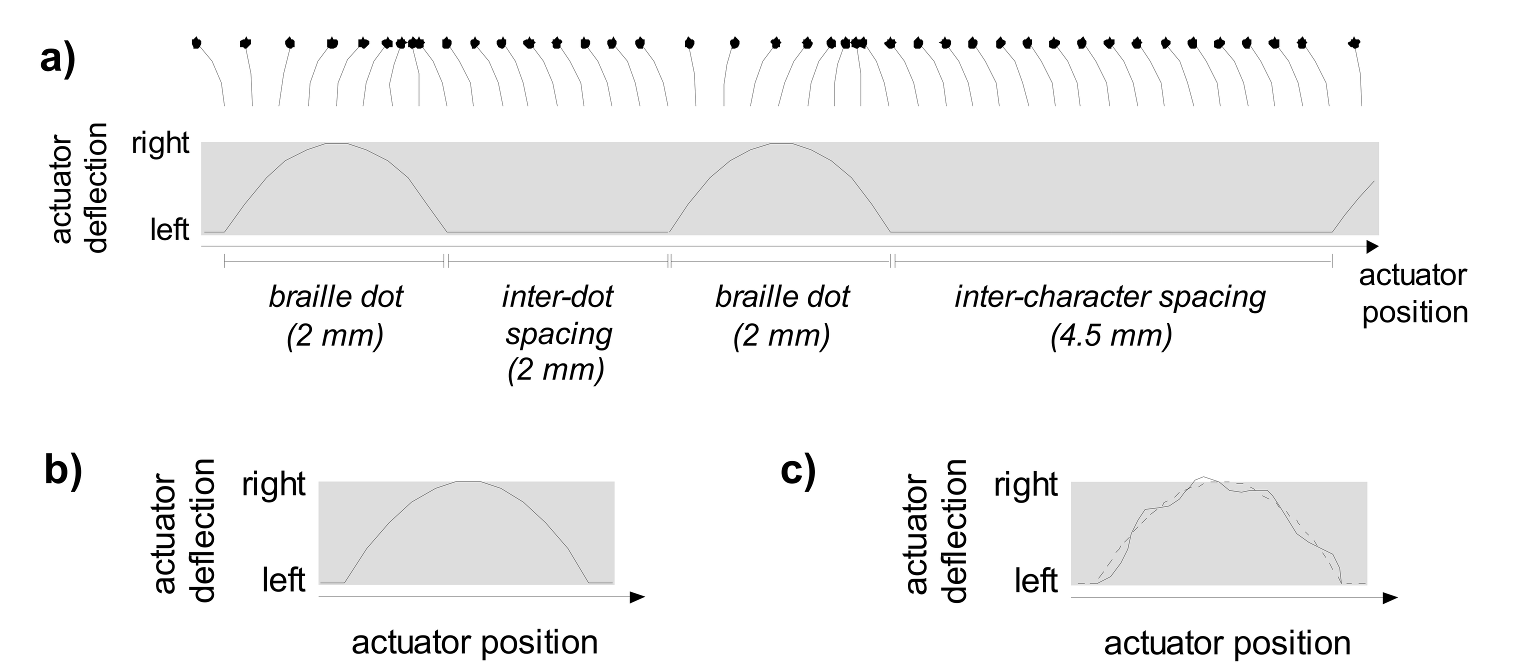
The VBD comprises a tactile display mounted on a frictionless slider moving laterally. The display has 12 piezoelectric benders, sandwiched at their base between neoprene spacers. The blades' corners were beveled to create a linear array of skin contactors with spatial period of 0.88 mm. When activated, the benders cause longitudinal deformations to the fingertip skin. The maximum deflection of the actuators is approximately ±0.5 mm. The position of the slider is measured by an optical encoder. Interfacing electronics permit the refresh of the 12 actuators at 500 Hz according to patterns programmed on a personal computer. Reading virtual Braille is done with the index finger by sliding the display laterally.



3. a) Sandwich construction, b) exposed contactors, c) exploration.

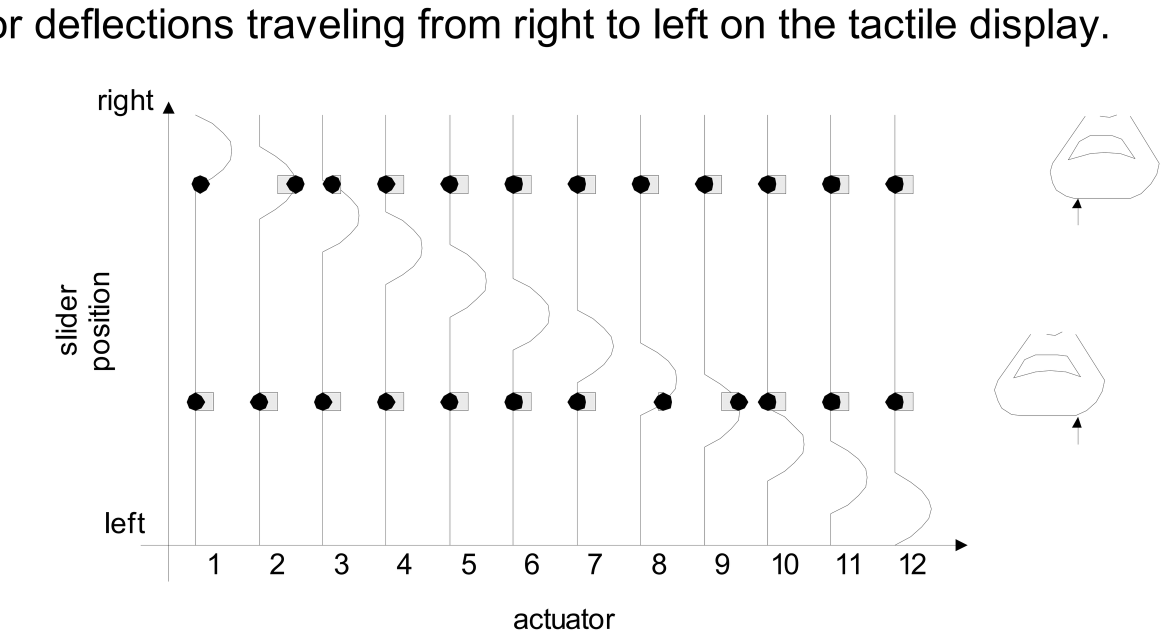
Skin Deformation Patterns

Experimentation led to the selection of a deflection-position function that closely approximates the sensation of scanning the finger over stationary physical Braille dots. As an actuator is dragged over a dot, its deflection follows the first half cycle of a sinusoid. A second possible virtual Braille representation, termed textured, consists of a small-amplitude, high-frequency sinusoid superimposed to the nominal sinusoid to enhance contrast.



4. Actuator deflection: a) traversing two dots, b) nominal dot, c) with texture.

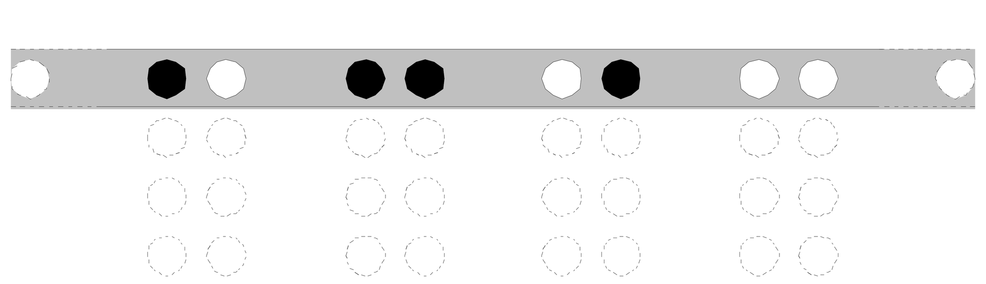
Moving the slider from left to right across a region containing a dot results in a wave of actuator deflections traveling from right to left on the tactile display.



5. Actuator movement with position indicators at two slider positions.

Pilot study

Five experienced Braille readers, all blind from birth, participated in the study. Four subjects had never heard about the VBD and the remaining subject was the fourth author who also participated in the design of the device.

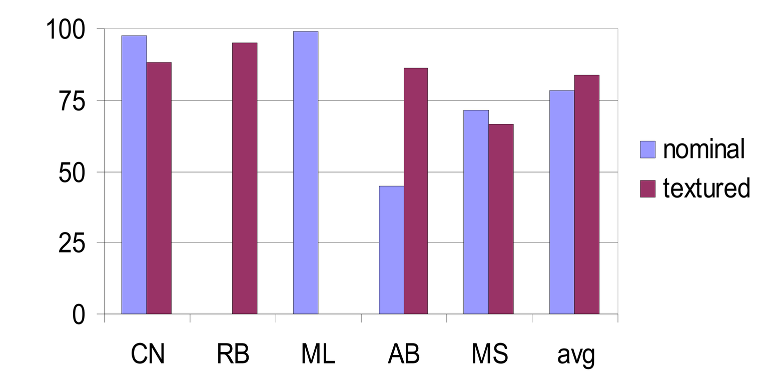


6. The four characters that can be represented with the VBD.

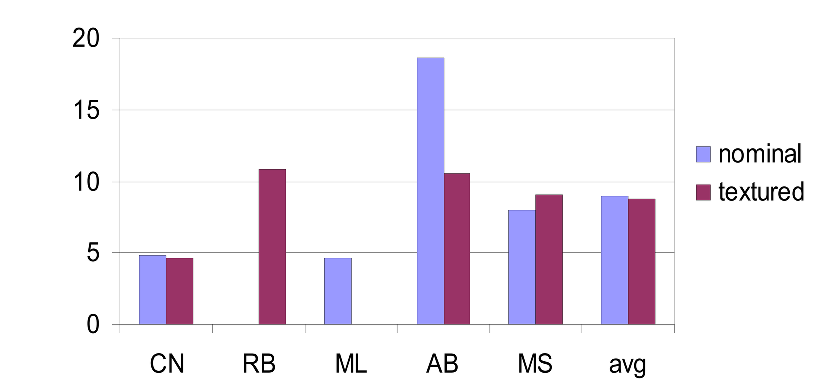
The reading task was designed to evaluate the legibility of sequences of the 4 characters that can be displayed on the VBD (••, •·, ··, ·•). . Subjects were asked to read individual 2-character strings surrounded by •• characters. A trial block comprised 80 strings with each of the 16 possible combinations appearing 5 times in a randomized order. Some subjects were tested under both possible virtual Braille representations (nominal and textured).

Results

The reading speed was below the typical Braille reading speed of 100 words per minute, likely because of the complexity involved in reading meaningless strings of Braille dots. The legibility – defined as the proportion of correct identifications of 2-character strings – was encouragingly high for most subjects. Results suggest that the effect of adding texture is idiosyncratic. Retaining the optimal virtual Braille representation for each subject, the legibility rates were between 71.3% and 98.8%. For some subjects, performance tended to decrease noticeably after about 50 trials when texture was used.



7. Legibility (%)



8. Average trial duration (s)

Regardless of the string, individual characters having one dot, •· or ·•, were harder to read than characters having no dot or two dots, •• or ·· respectively. The legibility also varied significantly from one 2-character string to another.

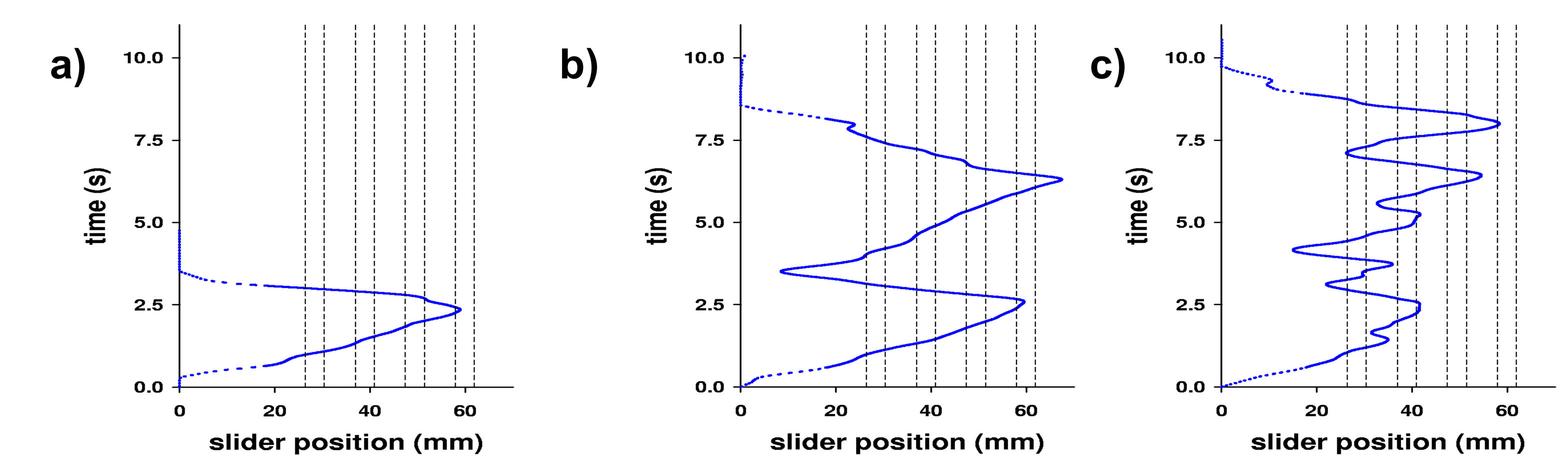
Table 3. Average character legibility (%)

•·	·•	••	··
83.3	88.9	92.2	98.1

Table 4. Average 2-character string legibility (%)

•· ·•	•· ··	·• ••	•· ••	•• •·	·• ·•	•• ·•	•· •·
66.0	74.0	76.0	77.5	78.0	81.0	81.7	84.5
·· •·	·• •·	•• ··	·• ··	·· ••	·· ·•	•• ••	·· ··
85.0	90.0	92.0	92.0	94.0	95.0	98.0	100.0

Three different reading patterns were identified. Subjects often made only one or two passes. However, they sometimes showed more hesitation, recognizable by back-and-forth motion over individual dots.



9. Typical reading patterns: a) one pass, b) two passes, and c) hesitation.

Conclusion and Future Work

This study suggests that reading Braille with devices using lateral skin stretch is possible even though subjects had little prior training with the device and the character strings were meaningless. The study also revealed the following issues:

- Reading with the VBD is difficult and requires a high degree of concentration.
- Prolonged use of the device seems to cause tactile fatigue (numbness).

Future work includes:

- Intensifying the sensation to realistically convey the illusion of a Braille dot.
- Experimenting more with various deflection functions.
- Extending the display to complete Braille characters.