Tactile Graphics Revised: The Novel BrailleDis 9000 Pin-Matrix Device with Multitouch Input

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Abstract. We describe the novel BrailleDis 9000 pin-matrix device. The refreshable device allows to present tactile graphics on a matrix of 60 times 120 pins. The pin-matrix device is made up of a newly developed type of vertical Braille module allowing for a compact assembly of all necessary components. Additionally, the pin-matrix device is touch sensitive and capable of detecting multiple points of contact. Using multitouch features, novel multimodal interaction cycles can be realized with the Braille display, such as a bi-manual sweep.

Keywords: Tactile graphics, visually impaired, assistive technology, pin-matrix device.

1 Introduction

Lack of access to computer systems for blind and visually impaired users has motivated a multitude of research activities and commercial product developments since the late 1970’s. Speech output and screen reader software such as JAWS, Dolphin or Hal have resulted in great improvements since. By using currently available assistive technology, visually impaired people are able to enter the labour market more easily and work in professions which previously could not be filled. In particular, visually impaired people are able to use most software as their sighted colleagues including standard word processing or spreadsheet programs. Even access to enterprise applications such as the SAP R/3 system can be realized by adapting screen readers to the user interface if scripts are provided.

Although the advent of screen readers and Braille displays had a great impact regarding accessibility, one of the main drawbacks remaining is the lack of access to mainly graphical information presented by modern computer systems. State-of-the-art Braille displays are not able to provide access to graphical information as their one-dimensional Braille row proves to be insufficient. Up to now, only large tactile displays can provide necessary context and bi-manual usage [15, 20]. Many research activities have been conducted successfully with large pin-matrix devices such as [12, 13, 14]. However, prototypes such as [2] never reached product status due to cost considerations and limitations in terms of manufacturing engineering since then. A broad overview of state-of-the-art developments and research can be found in [16].

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The paper is structured as follows. Requirements for tactile graphical displays are discussed briefly in section 2 followed by a description of the novel BrailleDis 9000 pin-matrix device in section 3. Section 4 gives an outline of still existing research and engineering challenges both in terms of hardware development as well as in terms of software development.

2 Requirements for Tactile Graphical Displays

Braille displays are an important assistive technology for enabling access by blind users to information provided by modern information technologies and computer systems. Commercially available Braille displays are normally constructed from forty or eighty Braille modules each providing eight pins ordered in two columns with four pins each. Each Braille module is then used to represent one text character using the six upper pins. The two bottom pins are dynamically lifted and lowered to represent the position of the cursor. Additionally, special buttons positioned relative to the corresponding Braille modules are used for routing and exploration of the rendered text. Standard Braille modules used for one-dimensional Braille displays are constructed using a horizontal shell which cannot be used for the construction of tactile graphical displays. The reason is given by the required packaging which does not allow horizontal dimensions greater than the area necessary for the pin sockets. Figure 1 shows photos of a conventional Braille module and its vertically constructed counterpart.

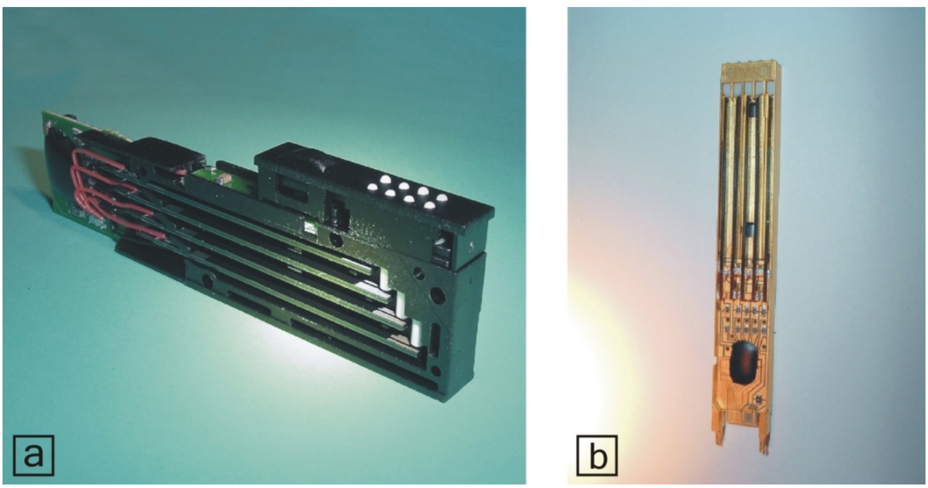

Fig. 1. Braille modules with (a) conventional and (b) novel vertical construction

Tactile graphical displays must provide an equal readability as commercially available Braille displays. Consequently, all Braille pins must provide a sufficient touch resistance which imposes specific challenges regarding the construction of vertical

Braille modules. Another requirement for tactile graphical displays is given by the actual time needed to refresh the display which should be within the range of currently available commercial Braille displays allowing for a comfortable interaction without distracting delays.

The user is not to be constrained to handle different input devices (i.e. moving from Braille display to keyboard and vice versa) to seek for control buttons located outside of the tactile area. The positioning of additional space-consuming routing keys used by conventional Braille displays is not applicable in large tactile graphical displays, as tactile contents is to be positioned equidistant or near to equidistant. Additionally, the distance between routing keys and rendered elements might be too far and cannot ensure continuous interaction without distracting interruptions.

The reference between tactile rendered object and control key has to be determined unambiguously from a user's point of perception. Several technologies are available to detect the user's finger position:

(1) User wears a pointing device.
(2) Fingers are observed by video cameras from above [1].
(3) User's impact of the surface is observed by video cameras from below.
(4) User's impact on raised pins [8], and
(5) Touch sensitive surface

We have chosen to provide touch sensitive input capabilities (5) as (1) is not very comfortable for the user, (2) cannot easily detect the intensity of the pressure when the finger is in contact with the surface, (3) is not applicable due to mechanical constraints, and (4) may not detect a finger's position if no pin is raised. A touch sensitive input device must determine the position of input with a resolution at least corresponding to finger's width or Braille character size, to be able to support direct manipulation of the rendered content as well as to realize command input via gesture recognition. Moreover, the palm of a single or multiple hands by one or several users may be involved when browsing the display.

3 The Novel BrailleDis 9000 Pin-Matrix Device

The HyperBraille project was started in mid 2007, motivated by the promising results of the BrailleDis project in 2001 [2] and the still existing gap regarding the presentation of graphics for visually impaired computer users. The new BrailleDis 9000 pin-matrix device consists of 7200 pins provided by 720 10 pin vertical Braille modules. It will be connectable via the standard USB 2.0 interface whereas an external power supply is necessary. A smaller prototype using the newly developed upright piezoelectric Braille modules is shown in Figure 2 in detail.

Within the project, the tactile graphical display developed within the BrailleDis project is being re-engineered. In particular, novel construction and manufacturing processes are being developed for upright Braille modules. The Braille dots are driven by piezoelectric actuators with a concave tactile surface.

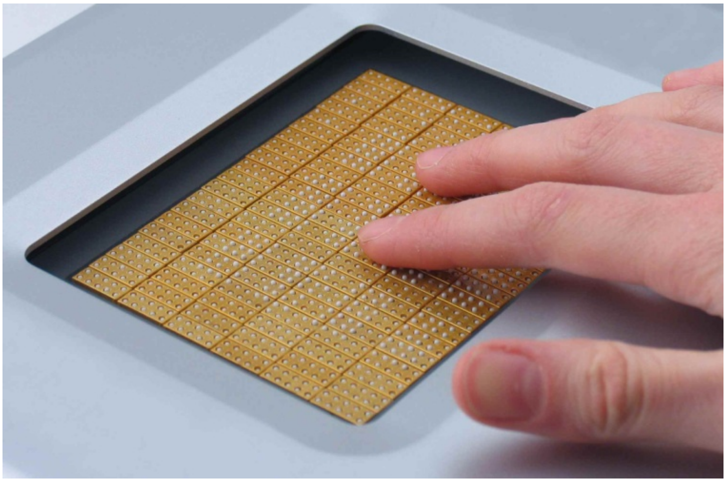

Fig. 2. Small prototype using the newly developed upright piezoelectric Braille modules

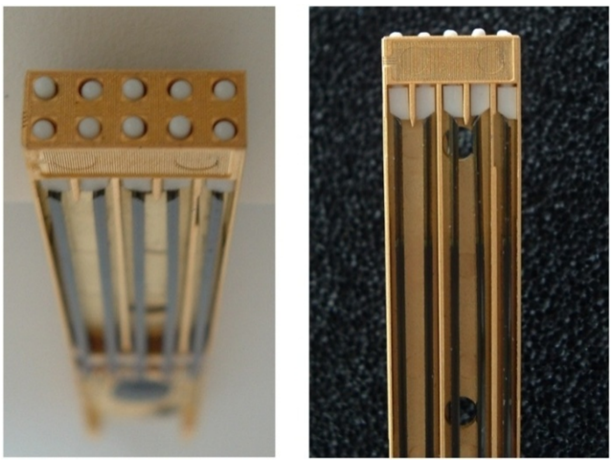

Fig. 3. Photos of the novel Braille module developed by Metec AG

The drive electronic uses low-power ASIC-electronics on MID-carrier with integrated IA-button data processing. Figure 3 shows two photos of the novel Braille module.

The most innovative part of the newly designed Braille module is its vertical construction. The construction of modules providing 2 times 5 pins allows for an easy replacement of damaged and defect modules. Each module is equipped with a separate sensor, separate actuator electronic, and is connected independently with the data bus. Consequently, defect modules do not affect the functionality of the remaining still operational ones (except when the defect directly leads to a short circuit of the data bus). As tactile graphical displays can be assembled modularly, different dimensions can be realized with only minor operating expenses. The data bus allows for a refreshment of the display each 50ms although the inertia of the piezoelectric actuators finally limits the refreshment time to a minimum of 150ms.

The actuation of the pins is realized via a basic spline gear. The cant of the piezoelectric actuators allows for shifting the pins, no additional parts are needed. The flattened contour at the end of the canted area allows for a high touch resistance of raised pins. Touch sensitiveness is provided by a capacitive measurement process implemented by the module surface. The measurement results are processed by corresponding ASICs within the Braille modules and are accessible via the data bus. A malfunction of one sensor does not affect other sensors ensuring continuous functionality of the tactile graphical display.

After describing the main technological innovations within this section, we will discuss the development challenges to be solved within the HyperBraille project in the following section.

4 Development Challenges

4.1 Construction and Manufacturing Engineering

One important aim of this work is the refinement of manufacturing processes regarding a newly developed piezoelectric upright Braille module which allows for a compact, portable and seriate construction of a graphical tactile display. The modules are manufactured using MID techniques whereas the highly complex module shells consist of special plastics material and are produced using injection moulding. The current manufacturing process includes a metallization of the module shell which constitutes the base for structuring isolation ditches for all three dimensions. The metallization must be reinforced by additional layers within the next manufacturing step after the isolation ditches have been applied by a special laser. However, this manufacturing process is very time consuming due to the comparatively high length of the isolation ditches. A different, faster MID process is being developed within the HyperBraille project. Instead of applying isolation ditches, trace pitches will be structured by laser. Significantly shorter production times are achieved, as also the complexity of the metallization process decreases. Based on first trials and small series implementation, reliable bulk production process is feasible.

4.2 User-Centred Design

Much research has been conducted covering the perception of visually impaired people regarding various types of tactile objects and representations [4, 10, 17, 18]. However, most of these experiments were based on setups using alternative tactile media as large tactile graphical displays have not been available. As the production of specific media such as tactile maps requires an immense effort, tactile media such as swell paper or Braille paper have not been used widely by visually impaired and blind people. As a consequence, the understanding and faculty of abstraction regarding tactile graphics differs greatly among this user group.

Most visually impaired people use computer applications in a non-graphical manner relying completely upon speech and optional tactile text output. Hence, no expectance could be constituted by most visually impaired and blind people regarding a tactile representation of graphical elements and objects such as widgets as well as regarding metaphors which have been implemented over time.

A user-centred design process is thus to be followed incorporating a thorough requirement analyses and pre-tests regarding initial design guidelines for the tactile representation of graphical tactile widgets and user controls considering actual research results such as [3]. During further development, continuous user tests will be conducted ensuring a maximum consideration of the actual user needs and requirements which are due to change when the tactile graphical display becomes available. Additionally, interaction offered by the tactile graphical display must be designed carefully as no previous research known to the authors has been conducted so far. In particular, users are being incorporated within the design process for singlehanded as well as two handed gesture input which is based on previous research results reported in [11, 19, 20, 21].

4.3 Designing Multimodal Widgets

Nearly all mobile phone display more then 120 by 60 pixels. Even if the pin-matrix device is large with respect to its tactile output, a force feedback device such as the Phantom supports a bigger working area. The key feature of a large tactile display is its multitouch, possibly bi-manual use both in the sense of touching and controlling an interactive system. In order to design tactile interaction for it we consider also other modalities such as speech, signals and sounds. This takes user's current experience with screen readers into account. Depending on the user's familiarity with Braille, speech can be dominating all interaction with applications or Braille, respectively. A fission component in a multimodal system may give priority to either of the two modalities to convey verbal information.

Braille is perceived via one or multiple points of touch, a trained Braille reader can read two Braille sequences in parallel with two hands when searching a term. More common is the overlapping use of both hands; one hand is reading towards the end of the line of text, the other hand is locating the beginning of the next line of text.
Hands may also control speech feedback, a technique very common for combining tactile graphics with speech. Listening to two or even more speakers at the same time is possible if spatial sound is generated. Currently only headphone based solutions based on head related transfer function (HRTF) are affordable. However, HRTF requires adaptation of parameters to a listener's ears and appropriate measurements is not available easily.

We extend therefore the categories of multimodal systems by the notion of a multimodal sweep, based on Heller's categorisation of touch [5]. Multimodal systems are the result of combining different types of fusion of modalities (combined, independent) and temporal structure of modalities (sequential, parallel) [6]. The pin-matrix device supports sweeping by one hand (manual multimodal sweep) and two hands (bi-manual multimodal sweep). A sweep has a longer duration than touching a pin or reading a Braille character takes. Bi-manual sweeps shouldn't be called simply parallel as the temporal structure has short-term and mid-term aspects. Sweeps can have rhythm and they can be synchronized among the hands.

For example, consider the scenario of non-modal windows such as a text editor and alongside to it a set of small windows showing font-size, font-colour, font-name etc.

A bi-manual sweep allows exploration of Braille text and reading at the same time character attributes. In addition, the multimodal bi-manual sweep can be integrated by a fusion component and provide acoustic verbal or non-verbal feedback. Depending on the type of sweep the user is informed about layout issues not inspected so far.

5 Conclusion and Outlook

A product-quality tactile graphical display such as the BrailleDis 9000 has the potential to open new perspectives for blind people and may become part of standard workplace equipment for the visually impaired. A user-centred approach has to take the different preferences of media into account when designing multimodal widgets for the pin-matrix devices. Through its multitouch capabilities it is not only suitable to show tactile graphics and large amount of text, it also supports hypertext links. A novel multimodal bi-manual sweep can be designed if appropriate fusion and fission of non-visual multimedia supports a multi-level temporal model.

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