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Braille line using electrical stimulation

A Puertas, P Purés, A M Echenique, J P Graffigna y G Ensinck
Gabinete de Tecnología Médica. Universidad N. de San Juan. Argentina
E-mail: amechenique@gateme.unsj.edu.ar

Abstract. Conceived within the field of Rehabilitation Technologies for visually impaired persons, the present work aims at enabling the blind user to read written material by means of a tactile display. Once he is familiarized to operate this system, the user will be able to achieve greater performance in study, academic and job activities, thus achieving a rapid and easier social inclusion. The devise accepts any kind of text that is computer-loadable (documents, books, Internet information, and the like) which, through digital means, can be read as Braille text on the pad. This tactile display is composed of an electrodes platform that simulate, through stimulation the writing/reading Braille characters. In order to perceive said characters in similar way to the tactile feeling from paper material, the skin receptor of fingers are stimulated electrically so as to simulate the same pressure and depressions as those of the paper-based counterpart information. Once designed and developed, the display was tested with blind subjects, with relatively satisfactory results. As a continuing project, this prototype is currently being improved as regards.

1. Introduction
The two main problems affecting the blind and vision-impaired persons are the information access and mobility and orientation constraints. The first problem has been addressed through numerous solutions made practical with a wide range of market-available technologies as well as other approaches under current research and development [1]. As an example of the latter, the Tactile Display has a growing role for information input. It is equivalent to a visual display, only that the information is perceived by skin contact; i.e. by stimulating the perceptive terminals of skin nerves. These are devices that present the information to the user by stimulating his/her perceptive nerve terminals on the finger skin by means of various stimuli: temperature, electricity, compressed air or mechanical variations (pressure or vibration) [2],[3],[4]. The disadvantages of using heat as a stimulus source lies on its thermal inertial; mechanical devices are prone to size, fabrication problems, fast wear off or malfunctioning, user’s fatigue, and so on. As regards electrical stimulation, the problem to solve is the suppression of the electric shock feeling, and to develop an adequate electrode-skin interface. This display presents fewer manufacturing and maintenance problems than, for example, mechanical means. Therefore, this greater robustness is translated into lower overall costs and longer system life. The prototype described here is a continuing research work that was preceded by former studies called “Display Táctil Electrocutáneo”[18] y “Celda Braille por Electroestimulación”[19]. The first research attained tactile feeling through functional electric stimulation that activates the skin’s mechanoreceptors. Various kinds of electrodes were tested, as well as different optimal characteristics (e.g., form, frequency and intensity of waves), and different tactile feelings. The second research paper describes the experimental model of a six-electrode Braille cell that, through electrical stimulation, attains pressure feelings similar to those of real-relief Braille cell.
The present development work is capable of transforming any text stored in a PC to a cell segment that simulates 32 Braille characters (engrams) of six electrodes each, using electrocutaneous stimulation, which allows to go dynamically forward or backwards as per character and/or text line.

1.1. Human skin structure

On a first step, the mechanisms of sensorial feelings were investigated. Various mechanoreceptors of the human skin were studied, mainly (1) Meissner corpuscles, or rapidly adapting mechanoreceptors (RA); (2) Merkel cells, or slowly adapting cells (SAI: slowly adapting type I); (3) Ruffini’s terminals, or slowly adapting mechanoreceptors Type II; and (4) Pacinian corpuscles (PC) [10], [11], [12]. Because the SAII population was very small, this alter group was excluded from the research. Some research works, e.g. [3], considered that the mechanoreceptors were capable of being stimulated separately and that the combination of said stimuli could generate different tactile feelings. Figure 1 [4] shows a crosscut view of the human swing. There, RA and PC perceive vibration, whereas SAI generate pressure feelings [5]. Sometimes RA and PC (rapid adaptation mechanoreceptors) are regarded as speed and acceleration sensors, because they respond to a single impulse to skin deformation. On the other hand, the slow adaptation mechanoreceptors (SAI) is characterized as the position of displacement sensors, because they respond to the intensity and duration of the stimulus.

1.2. Electrical stimulation mechanisms

On a second stage, we considered the research works on electrical stimulation mechanisms, which is performed with an electric current source on the skin, with an indirect activation of the nerves. This way, cathode (negative) current activates the nerve cell axons oriented horizontally on the skin surface. On the contrary, when applying anode (positive) current, the nerve cell axons oriented vertically (like the RA axon) are stimulated this time. According to the studies made [2]-[9], the mechanoreceivers are sensitived to stimuli in the 40-600Hz range.

![Figure 1. Cross section of human skin.](image)

RA: Meissner corpuscle, SAI: Merkel cell, SAIi Ruffini terminal, PC: Pacinian corpuscle.

As regards the duration of the stimulation pulse (200 μs), all the research work we have reviewed [5], [13], [15]-[17] on electrocutaneous stimulation employ this value. This may be linked to the
adjustment or habituation phenomena that take place in nervous fibres, because –for example- SAI fibres respond to these thresholds [14].

Nerve excitation by electric current causes a very clear tactile feeling (pricking or pressure). This means, however, is a rather uncomfortable shock while approaching or moving away the finger from the electrode [19]. Since the current is constant, regardless the load (impedance of the finger), when getting the finger closer or away from the electrode makes the section increase or decrease. This inconvenience is eliminated by voltage excitation because the voltage is independent, regardless the load amount. The current flowing through the skin is proportional to the skin impedance. Therefore, regardless the fingertip area involved in the excitation, the current intensity will be regulated automatically.

![Stimulation signal (voltage pulse)](image)

**Figure 2.** Stimulus waveform.

2. Development

2.1. Experimental Model

The simplified block diagram of Figure 3 shows the developed experimental model.

The Braille line is controlled via Windows®-based software fed with the text to be read by the user. The reading process is made through 32 cells of 6 electrodes each, which allows reading 32 characters per line. Communication between the PC and the device is made via the UART port with RS-232 standard, or via the USB port. All currently market available PCs have one or both connection plugs a convenient feature that renders the design great versatility. This way, the 32 characters of the line are stored in the RAM memory of the MC68HC908JL3 microcontroller, altogether with the table for converting ASCII into Braille code.

The text can be scrolled forward or backward by means of two push buttons located on the right-end of the pad. They send the signal to the PC to let the line go forward or backward.

The device presents as well a system to sense in real time the finger position and, thus, place the character corresponding to said position according to the entered text. For each cell, the system incorporates photo-detectors circuits. They were chosen so, because they are activated by a light source rather than by an electrical input. This sensor type allows the sensor arrangement be electrically isolated from the reading finger, which prevents interference and false stops when the stimulating signal flows through the finger. The output from each photo-detector circuit goes into a priority encoder, where the activation of any of the 32 outputs generates a 5-bit code to be input into the
microcontroller. This coding is necessary because the microcontroller has a limited number of input/output terminals. Therefore, the number of necessary terminals is reduced from 32 to just 5.

The stimulation of the mechanical-cutaneous receptors is performed using 6 amplifier circuits operating as switches that generate the voltage signal having the waveform, frequency amplitude and pulse width as shown in Figure 2. The stimulation signal amplitude can be regulated via a potentiometer handled by the user.

![Image](image_url)

**Figure 3.** Block Diagram of the Experimental Diagram

The energizing circuits are powered via a 240V dc linear power supply, V-I (folded type) characteristic with maximum output current limitation set at 4 mA and 2 mA for short-circuit. This power supply employs an isolation transformer. Finally, the Braille Pad receives the stimulation pulses that represent the Braille characters when the user presses his/her finger on the pad.

### 2.2. Description of the Braille line

The 192 stimulation electrodes are divided into 32 cells of 6 electrodes each. These electrodes were build with 1.5 mm dia. copper wire. This material was chosen on account of its high conductivity, low cost and great malleability.

The stimulation electrodes that conform each cell were arranged according to the so-called Integral Table of the Braille System (two columns of rows of three rows each). The standardized distances among electrodes, and the cell arrangement in such a table can be seen in Figure 4 [20].

The electrodes corresponding to the same relative position in each cell are internally connected to each other. Therefore, there is always a same character appearing in the 32 cells. This feature brings an advantage, because only 6 electrodes have to be controlled at any one time, and not all 192 (32 x 6) and, thus, costs are lowered and the design size is reduced as well. From the user’s viewpoint, this poses no inconvenience because just one character is read at a time, and not all characters altogether. To design the cell, the information gathered in previous experiences was taken into account [19], besides meeting the requirements of simplicity and reduced costs and size.
The electrodes are housed in a finely polished resin housing (Figure 5), altogether with the buttons for going forward or backwards, and the photo-detectors. Polishing is made so as to avoid that any surface discontinuity may mistakenly be interpreted as a stimulus signal from the electrodes. The photo-detectors -lightened by a 16W fluorescent light source- are placed under each cell, protruding about 2mm from the polished surface of the pad. The blind user can thus feel this unevenness and have a reference of the approximate location of each cell. As a stimuli-return electrode, a mobile electrode was used that is built with a metal plate placed on top of an elastic band that is fastened around the finger (Figure 6) [18], [19].

3. Experience

3.1. Methodology
Experiences were made according to the premises of achieving clearly defined stimuli; that is, always attaining a pressing feeling on the finger tip. First, a series of preliminary trials are carried out with 5 normal-vision persons, so as to know the variability range of parameters that reach a better localization and reception of stimuli by the mechanoreceptors). Said parameters were the pulse width duration and the stimulation frequencies. A second set of experiences was made with 5 adult blind and visually impaired subjects belonging to the School of Special Education “Louis Braille” who show an intermediate performance level in Braille system reading. This performance was evaluated through a reading drill on paper records, previously to the experience.

The following protocol was defined for the experience:

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**Figure 4.** Array for of each stimulation cell.

**Figure 5.** Braille Pad

**Figure 6.** Return Electrode
Clean the Braille Pad and the finger tip with an alcohol-dipped cotton bunch so as to ensure a clean electrode surface and to decrease the skin impedance.

- Put and fasten the return electrode on the finger to be stimulated.
- Using the PC software, input the text to be read.
- Make the adjustments for stimulus intensity using the intensity control located on the left side of the device. This adjustment is necessary to guarantee that the stimulus perception is comfortable to the user.
- Start reading from the pad.

At first, low voltage stimuli were used, with progressive voltage increases depending on the individual’s sensibility. One electrode was used in this first stage. Then, the experience was completed by using the entire prototype operating normally.

3.2. Results
For all cases, the frequency of stimulus signal that achieved better results was approximately 1 KHz, with a 200μs pulse width.
The perceived feeling was a pressure combined with a little vibration.
The persons subjected to the experiences said that the perceived feeling is much softer and less traumatic that the counterpart stimulation with electric current. Thus, the electric shock feeling experienced in previously reported devices is eliminated with this prototype.
On the other hand, although at all times the number of active electrodes in each cell was detected, their relative position was not detected in form. The reason may be found on the stimulation of the axon of a mechanoreceptor located in distal form.

4. Conclusions
According to the experiences made, the prototype worked correctly as regard correlativity between the characters fed by the PC and those appearing on the Braille pad, according to the finger position on the pad. No inconvenience was detected when making the reading line go forward or backward. On such a sense, the prototype is robust, reliable, of light-weigh and low cost.
As regards the perceived tactile feeling, not all the premises were met ( i.e, to achieve clearly defined stimuli, while always attaining a sheer pressure feeling on the finger tip). Instead, combined pressure with vibrations was felt and, in some instances, character interpretation errors were noted. However, the lack of definition and character acknowledgement for these cases can be sourced to the striking difference between conventional Braille reading (the subjects normally use both hands, mainly the index fingers) and the reading form proposed here (due to constructive and design requirements)
Compared to previous works, a significant advance was attained as regards the stimulation system, because the way of generating the stimuli was changed by using voltage instead of current. This change caused a softer, user-friendly feeling that eliminates the rejection of the users.

5. References


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