A Portable Device for Optically Recognizing Braille – Part I: Hardware Development

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This is the first of a pair of papers that describe a prototype portable device for optically scanning embossed Braille and conversion of the scanned text to binary Braille representation. This prototype has been developed in conjunction with the Association for the Blind (WA). An application to convert the literary Braille code to expanded text has also been implemented and is described in the second article [12]. The system developed utilises a hand held scanner that captures the embossed Braille image, in real time, via a linear 128-pixel CCD array. A Texas Instruments digital signal processor performs recognition processing.

1 Introduction

The Braille system is the preferred medium for written communication by persons with total blindness or very low vision [12]. The device described in this document is not intended solely for use by the vision impaired but more by non-Braille users in education and mainstream workplaces.

Students with severe vision impairment are now taught in mainstream schools. The method of note taking, assignment, homework presentation and general recording of verbal instruction is achieved on a manual Braille typewriter. However many teachers of these students are not Braille literate. Work completed by the student, in Braille, must therefore be translated by a third party into a format that may be read by the instructor. This situation may be extended to those in the workplace who wish to use Braille notes in their employment and would wish non-Braille users to access said written information. When a fellow employee wishes to check this correspondence, they must either ask the Braille user what is written or the vision-impaired person (VIP) must translate their work for use by others. This problem reduces to the fact that VIPs are comfortable with Braille but the sighted are not. Therefore, a communications barrier exists between the sighted community and Braille users.

In some cases a person will lose sensitivity in the fingertips leading to an inability to continue reading Braille. Diabetes is a major cause of blindness with one symptom being Diabetic Peripheral Polyneuropathy, a condition that leads to nervous dysfunction in the extremities. In many cases of head injury and in geriatrics, similar symptoms exist. This may cause a great deal of trauma, as the person will no longer be capable of written communication, if they are primarily a Braille user. A device such as the one described herein would allow persons in such a situation to continue to read their preferred method of written communication.

2 Background

Although a great deal of research has been done and many commercial products are available for text recognition commonly known as Optical Character Recognition (OCR), little has been done successfully to produce a Braille version of OCR. There is at present no available portable system for converting embossed Braille into either an electronic, printed or speech output format. Mennens et al [8] give an excellent summary of recent work in this field. Whilst of great interest to this work, the approach and technology used in [8] differs substantially from that is proposed in the present work reported in this paper.
Two possible methodologies were considered for gaining the image for processing; they being, tactile films and optical image processing. Tactile films such as piezo electric polyvinyledine fluoride films were discontinued due to the fact that pressure exerted on the embossed Braille will eventually degrade the copy and the large variance in dot height as Braille wears may be difficult to allow for.

Optically scanning the Braille appeared to be the best solution. Area Charge Coupled Devices (CCDs) would involve very large amounts of data processing to extract the image and this would have made real time processing difficult. The most promising method of image capture was the linear CCD arrays, in particular the Texas Instruments TSL215 128 pixel array. This unit will scan over the text in a vertical manner and have the image clocked out to the image processing board. The linear array may be clocked at up to 500kHz with the output in a serial form. This may be achieved as a single 128-bit stream or two parallel 64-bit streams. Position of the cell within the window will not be of a major concern as the algorithm proposed [11], will examine changes within defined areas of the captured slice. The method proposed utilises three distinct subsystems.

1. Image capture
2. Processing platform / Real time recognition
3. Output / user interface

The last sub-system will not be considered, as the user interface was not defined thereby allowing connection to various output display devices.

The main requirements are the capture and translation of literary, or grade-two Braille, in real time, with a portable device. This stipulation excludes methods that include flat bed scanners, as the use of such a standard device requires the full-page image to be stored prior to recognition and therefore may not be considered as providing the decoded text as the recognition process executes.

3 The Braille System

Braille is a system of embossed (raised) signs, which are formed by six dots arranged and numbered as in figure 1. Eight dot Braille is in limited use in the computer application area and is used in the display of text attributes. Therefore, eight dot Braille will not be considered further. Each dot can be set or cleared giving $2^{6}-1$ (63) possible characters in the code. As can be seen from this available number of combinations, not all characters may be represented directly by this system. (i.e. 26 upper case letters +26 lower case letter +10 numerals + punctuation marks greatly exceeds 63) [3].

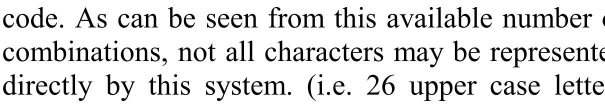

Figure 1: The Braille cell [7]

Therefore, a system of contractions and abbreviations for words and letter combinations is used. This is commonly termed grade 2 or literary Braille. Each of these cells (Braille characters) is context sensitive, depending on the absence/existence of previous, following and symbol characters in the string being read.

All dots on a Braille page should fall on an orthogonal grid. When texts are printed double sided (Interpoint) [4], the grid of the interpoint text is shifted so that the dots fall in between the primary side dots. This is illustrated in right hand side of figure 1. For reference purposes, a particular combination may be described by naming the positions where dots are raised, the positions being universally numbered 1 through 3 from top to bottom on the left, and 4 through 6 from top to bottom on the right [8]. For example, dots 1-3-4 describes a cell with three dots raised, at the top and bottom in the left column and on top of the right column. In the original French language, in English and all other languages written in the Roman alphabet, that pattern would most often be used for the letter "m". It can also have other meanings depending on language, Braille code and context.

The basis of the various Braille codes for the world's natural languages is a straightforward assignment of most of the dot patterns to letters of the alphabet, punctuation marks and other symbols [10]. This is done with a certain consistency, quite often with reference to Louis Braille's original assignments. For example, the letter "m" mentioned above would be used for ‘mu’ in Greek, and ‘mim’ in Arabic, both of which have an "m" sound. It is worth noting that it is not considered important for a Braille character to resemble the corresponding print symbol in "shape" [2].

In Braille, dot height, cell size and cell spacing are always uniform. Such indicators in Braille must handle so many significant characteristics of the text, such as italics used for emphasis. An exception is that of formatting, such as the centring of main headings, which is commonly used in Braille in much the same way as in print.

Separate Braille codes are used for notation systems other than natural languages, such as music, mathematics and computer programming, and for highly specialised pursuits such as chess [1]. The basis of such codes remains an association between the 64 possible Braille characters, or distinct sequences of such characters, and the symbols and other notational elements of interest. There is current research, under the auspices of the International Council on English Braille (ICEB), as to whether some of these separate codes, notably for mathematics and the sciences, should be combined along with the literary code into a single Unified Braille Code (UBC) for English. [2,3]

As stated the 64 distinct characters are insufficient to cover all possible print signs and their variants, it is necessary to use multi-character sequences for some purposes. Often this is accomplished by using certain characters as "prefixes" or "indicators" that affect the meaning of subsequent cells. For example, in English a dot 6 before a letter indicates that the letter is a capital, whereas otherwise it is understood to be lower case. For another example, dots 3-4-5-6, called the "numeric indicator", causes certain following letters (a through j) to be interpreted as digits [8].

The size of the Braille cell is such that only 25 lines of 40 cells each, that is 1000 characters, can fit on a page of the usual size, (11 inches wide by 11 to 12 inches deep). This contrasts with the 3500 characters that will fit on a standard, smaller, typed page. Moreover, Braille paper must be much heavier to hold the dot formation and the dots themselves considerably increase the effective thickness of a page. The result is that embossed Braille is very bulky. To mitigate this problem somewhat, most larger Braille books are published in "interpoint", that is with the embossing done on both sides of each sheet, with a slight diagonal offset to prevent the dots on the two sides from interfering with each other (figure 1).

Partly because of the bulk problem, and partly to improve the speed of writing and reading, the literary Braille codes for English and many other languages, employ contractions that substitute shorter sequences for the full spelling of commonly-occurring letter groups. Contractions such as TH may not be used across syllable boundaries. For example it may be used in the word THis but not in shorTHand [7]. This creates major problems in computer decomposition of grade-two Braille with respect to syllable boundaries.

When contractions are used, the Braille is usually called grade-two in contrast to grade 1 transcription where all words are spelled out letter-for-letter. In English, which has 189 contractions, almost all Braille is grade-two.

3.1 System Block Diagram

To enable the scanning of Braille material a scanner or camera assembly was designed and constructed. The device is a hand held unit that is scanned over the Braille line by line and the results are converted to text in real time, so as scan continues, text is displayed, allowing the user to look at beginning of sentence and see if it is the section they wish to decipher, as would be the case with a sighted reader of standard text.

Braille has unique problems to overcome when optical character recognition is attempted. The first point of consideration is the illumination of tactile mediums. Braille dots are raised approximately 0.5mm from the paper surface with the additional property of interpoint Braille being depressions in the surface of approximately 0.4mm (allowing for paper thickness). To correctly illuminate the cells, an “ideal” cell was created and ray-tracing methods applied. From this data it was determined that verso cells (figure 1) may be differentiated from recto cells as long as illumination was oblique. Further, diffusion of reflected light could be corrected by the use of a lens system to focus the image. The image may then be captured by the linear CCD array.

In order to allow correct image capture, it is necessary to have known the linear rate of movement of the scanner with respect to the Braille cells. A code wheel arrangement was constructed to provide an interrupt at set intervals of distance. This code wheel arrangement triggers a “slice” capture at a rate of 200 slices per inch. These slices are then processed by the DSP to give the equivalent binary Braille code.

The hand held scanner unit consists of a CCD and lens housing, as depicted in figure 2. The CCD is controlled by the timing board and transmits the vertical image slices, as an analog waveform, to the digital signal processor. The code wheel assembly triggers an image slice capture on the DSP at 200 slices per inch. The host computer serves to convert the recognised image to expanded text.

3.2 Image Capture System

The image of the Braille cell is captured via a gradient refraction index lens and linear CCD array. Illumination is provided by a light bar consisting of four HE red LEDs encapsulated in a diffused medium to provide a even level of illumination over the cell area.

3.2.1 Illumination

Illumination is supplied by an array of 4 red LEDs. The package supplies 45mCd luminance intensity at 635nm wavelength. This corresponds to the peak sensitivity of the linear array CCD of 600 to 950nm. Additionally, it was found that discolouration of the Braille paper is less noticeable under this particular wavelength of illumination when compared to the yellow, green and white illuminations also tested. Physical placement of the LED array was determined by trial and error. An angle of incidence of approximately 20 degrees with respect to paper surface and a driving current of 40mA rendered highly discernible results.

3.2.2 The Lens System

Gradient index micro lenses have a radial varying index of refraction that causes an optical ray to follow a sinusoidal propagation path through the lens [9]. They combine refraction at the end surfaces along with continuous refraction within the lens. Such lenses are said to have a pitch of 1.0 when its length is such that a ray completes one sinusoidal period in travelling through the lens [9]. Information contained in Newport, 1997 stated that for a working distance (Braille to lens) of 1mm and a focal length to CCD of 3mm, that a pitch of 0.29 was most suitable under red visible light.

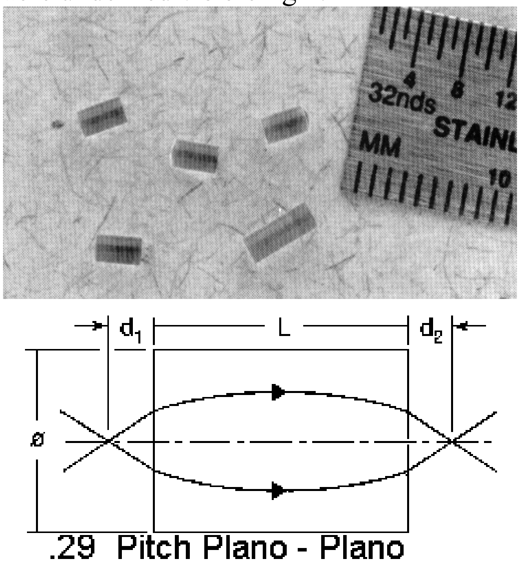

Figure 2: Gradient index lens properties.

The lens system used contains a 2 by 12 array of such elements mounted in the camera housing as detailed in.

3.2.3 The Linear CCD Array

The image sensor is comprised of two sections of 64-charge mode pixels arranged in a 128x1 linear array with each pixel having dimensions of 120μm by 70μm with a 125μm center-to-center spacing.

3.2.4 Code wheel Construction

To enable the rate of movement of the scanning device to be determined, a code wheel mechanism was constructed. The original unit was obtained from Robotron Pty Ltd [5], and modified to suit the scanner arrangement. This device consists of a slotted disk driven via a gear reduction to supply a resolution of 200 vertical slices per inch. The slotted disk interrupts an infrared beam generated by a spectrally matched narrow beam angle infrared emitter and received by a filtered narrow acceptance angle detector to provide the sensing signal as depicted in.

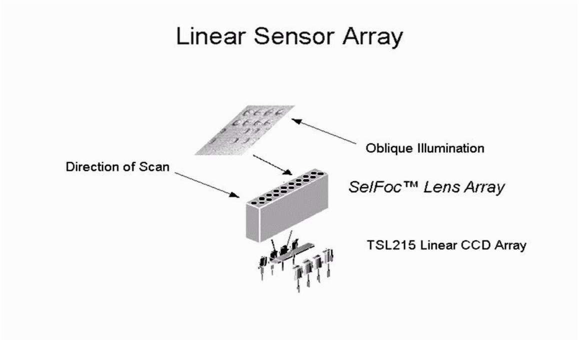

Figure 3: Selfoc lens and linear array arrangement.

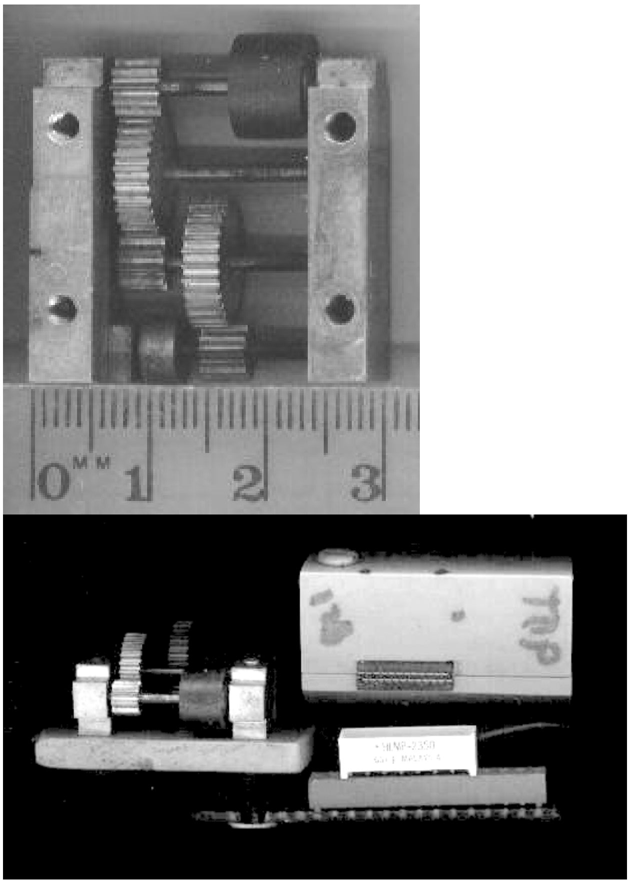

Figure 4: Code wheel gears and under side view of scanner assembly.

Details of the construction are depicted in figure 4. Note that two code wheel discs were used, one rotating proportional to the linear rate of movement and one in a fixed position. This acted similar to a shutter and resulted in a greatly improved timing signal generation.

4 Conclusions

The most significant achievements of this work can be separated into two areas: The image capture of a tactile medium and the digital signal processing recognition system.

As stated earlier, the capture of a tactile written medium has unique demands. The method of capturing the image of an embossed cell by selfoc lens, oblique illumination and linear CCD array provided excellent imaging and allowed for a much reduced level of processing when compared to area arrays and commercial flatbed scanners. It must be stated, however that this style of scanner has a major disadvantage. It is difficult to keep vertical with respect to the Braille line and tends to wander off the ideal alignment. Further observations with respect to the overall performance of the system are given in [12].

4.1 Recommendations for Future Development

There are several aspects of the prototype developed (figure 6) that require further development to bring this device to a point that it is of practical use, as explained in the sections below.

4.1.1 Linear Motion Detection

By replacing the present code wheel arrangement with a quadrature linear motion detector, that is, one that has two outputs that are 90 degree out of phase, the direction of scan may be discerned. Normal hand jitter or missed characters that are re-scanned by moving the scanner backward over the line may be easily allowed for and corrected. Such devices are commonly available from suppliers such as Hewlett Packard. The suggested device is the HP 9100 two-channel optical incremental encoder module [6]. This device, when coupled with a code wheel, translates rotary motion of a shaft into a two channel digital output. Due to the integrated phasing technique, the digital output of channel A is quadratures to that of channel B [6].

This will also allow for decreased resolution to 75 scans per inch which is ample for Braille as the characters are of fixed size and quite large (4mm by 8mm). By doing so, processing time is reduced and a cheaper processor may be used. The scan rate would also increase from its present half inch per second.

4.1.2 The Illumination System

The illumination is required only during the integration time of the CCD. By illuminating the Braille cell only when linear motion is detected for the integration time of 10 ms would constitute a major power saving. This is a necessary consideration in portable devices. In conjunction with the proposed decrease in linear resolution, the Braille illumination period would be reduced by a factor of 75/200 if the same scan rate was maintained.

4.1.3 Ergonomics and Alignment Method

The device in its prototype form is very hard to keep vertical and on the Braille line. Development of the ergonomics would improve recognition and ease of use by keeping the image within the defined lens area.

By incorporating a second roller on the scanner assembly, the lens may be kept better aligned. If the lens begins to move off the Braille line, the lines above or below will be felt as they pass under one of the rollers. Having two rollers will also have the effect of forcing the scanner to move in a straight line with respect to the Braille line being scanned. Figure 5 illustrates a possible method of including this change.

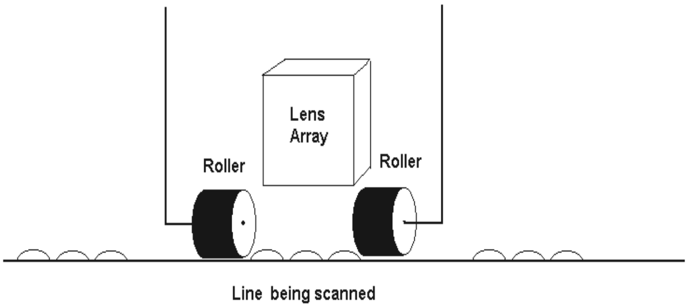

Figure 5: Improving alignment

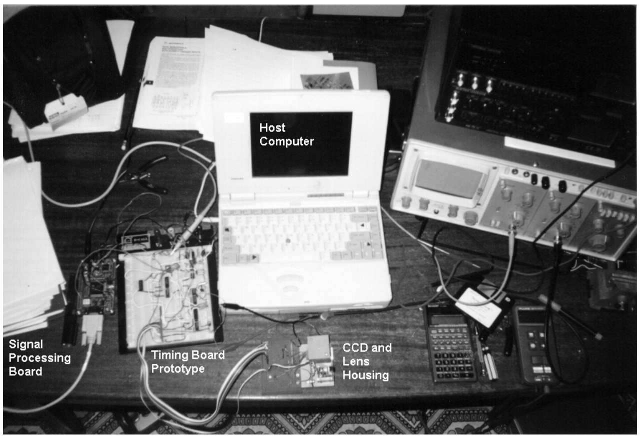

Figure 6: The Prototype System

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