Regular Feature Extraction for Recognition of Braille

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Abstract

Braille, a touch-reading system for the visually impaired people was first introduced in 1825 by Louis Braille. Editing and reprinting of Braille that were embossed on papers are time consuming and labour intensive. The aim of this paper is to present an automatic system to recognize the Braille pages and convert the Braille documents into English/Chinese text for editing.

1. Introduction

Braille is a system of touch reading and writing in which raised dots represent the letters of the alphabet. Braille also contains equivalents for punctuation marks and provides symbols to show letter groupings. Braille is read by moving the hand or hands from left to right along each line. Both hands are usually involved in the reading process, and reading is generally done with the index fingers.

Braille was first introduced in 1825 by a French scientist Louis Braille [1]. He took a secret code devised for the military and saw in it the basis for written communication for blind individuals. The original military code was called night writing and was used by soldiers to communicate after dark. It was based on a twelve-dot cell, two dots wide by six dots high. Each dot or combination of dots within the cell stood for a letter or a phonetic sound. The problem with the military code was that the human fingertip could not feel all the dots with one touch.

Louis Braille created a reading method based on a cell of six dots. This crucial improvement meant that a fingertip could encompass the entire cell unit with one impression and move rapidly from one cell to the next. The system of embossed writing invented by Louis Braille gradually came to be accepted throughout the would as the fundamental form of written communication for blind individuals, and it remains basically as he invented it.

Due to the size of a Braille cell, a page of normal size, about 11 inches wide by 11 inches high, can hold not more than 1000 characters. Braille paper must also be thick enough to withstand a certain amount of pressure for tactile sensing. Therefore, printed Braille documents are very bulky. To mitigate this problem somewhat, most Braille documents are printed in “interpoint”, that is with the embossing done on both sides of each page, with a slight diagonal offset to prevent the dots on the two sides from interfering with each other.

This makes the translation process more difficult as the recognition technique employed by the translation system is based on the visual perception of the Braille document, but not tactile sensing as used by the visually impaired users.

2. System Overview

The Braille recognition system consists of six operations:

- *Scene constraints*: exploits and imposes the environmental constraints to reduce the complexity of all of the subsequent operations to a manageable level.
- *Image acquisition*: captures a Braille page and convert it into a digitized image array.
- *Pre-processing*: modify and prepare the pixel values of the digitized image for subsequent operations. This includes contrast enhancement and adjustment, noise removal and edges sharpening of the Braille dots.
- *Segmentation*: separates the acquired image into foreground (dots) and background regions. This operation also separates the front-faced dots and back-faced dots.
- *Feature extraction*: Extracts the Braille dots and groups them into cells.
- *Interpretation*: converts the Braille cells into their corresponding English/Chinese text.

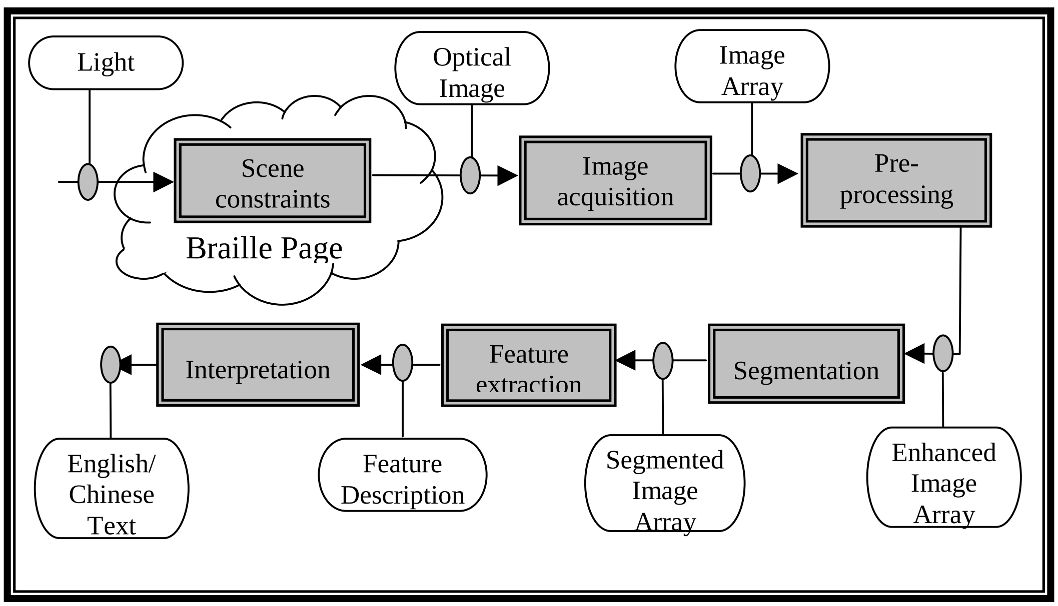

Figure 1 System overview

The following sections present each operation in more detail.

2.1 Scene Constraints

Scene constraint is the first operation of the system, the two principle aims of this operation are: to maximize the use of prior knowledge of the scene, i.e. by exploiting existing knowledge; and to trivialize the problem of image analysis as far as possible, i.e. by effective imposition of constraints [2]. Bearing these two aims in mind, it was noted that most of the Braille pages were embossed on both sides of a white paper, and the dots were embossed with a sphere shape. Taking consideration of these characteristics, it was decided that the Braille pages should be illuminated with a yellow polarized light source placed at an angle about 45 degree away from the page top. As the dots on the front face are raised above the page and those on the back face made holes on the front side, these convex and concave characteristics of the dots reflect the illumination light in two different angles, creating an illuminated hole at the top half of the captured dots for those front face Braille dots and at the bottom half for those back face dots.

2.2 Image Acquisition

This operation is concerned with the process of translation from light stimuli falling onto the sensing elements of a capturing device to digital values. The capturing device used in this experiment is a digital camera, which is placed directly above the Braille page as shown in figure 2. The captured digitized image has a 512 * 512 pixel resolution with each pixel representing an 8-bit gray scale value. As the Braille page is 11 inches by 11 inches, the 512 by 512 pixel resolution will not distort the original x-y aspect ratio.

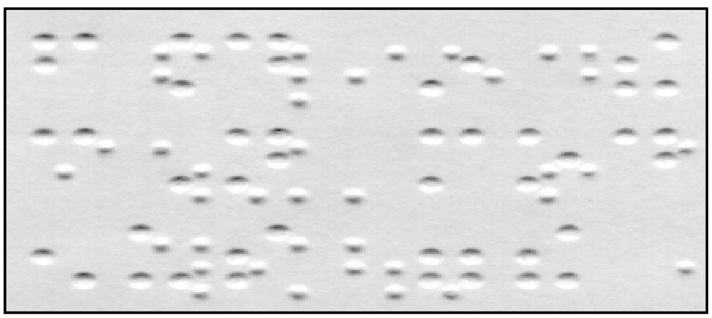

Figure 2 The Captured Braille Specimen

2.3 Pre-processing

The pre-processing operation consists of two sub-operations: noise filtering and edge enhancement. During image acquisition, impulse noise was introduced in the image. These noises generally manifest themselves as random fluctuations in gray-level values superimposed upon the "ideal" gray-level value, and it usually has a high spatial frequency. Therefore, a low-pass spatial Gaussian filter is applied to the image to attenuate the high spatial frequency noise form the image while at the same time preserving the detailed edge information of the Braille dots [3]. The objective of edge enhancement is to sharpen the fine details of the image that has been blurred. The process performs two independent filtering operations using convolution Sobel kernels [4,5] denoted X and Y, the resulting values are obtained by:

$$\text{output} = |\text{convolute}(\text{input},X)| + |\text{convolute}(\text{input},Y)|$$

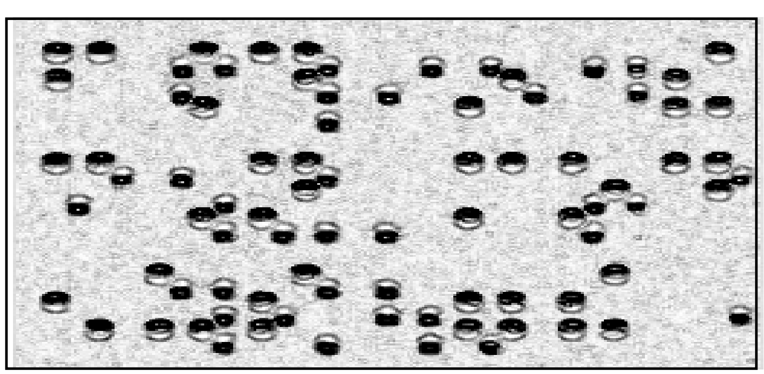

Figure 3 Result of Edge Enhancement

2.4 Segmentation

Since Braille pages contains dots (foreground) and page (background) only, analysis a binarised image is much simpler than that of gray-scale images. For a simple global threshold, where the image histogram is bimodal or has easily identifiable peaks and valleys, the selection of the threshold value is straightforward. However, the digitized Braille page images are noisy, and there are considerable spread in gray level values, the selection of threshold value is problematic [6]. Our approach to improving the segmentation process is to consider a histogram made up of only those pixels that lie at or near the edges of the Braille dots. The resulting histograms contain sharper peaks and lower valleys. To determine which pixels lie on or near an edge, the Laplacian of Gaussian operator $\nabla^2 G$ [7] is first applied to the entire image to identify the edge pixels. The average gray-level value of these edge pixels will then be used as the global threshold value. By experimental results, the threshold value is 100 for single-sided Braille pages and 85 for double-sided pages.

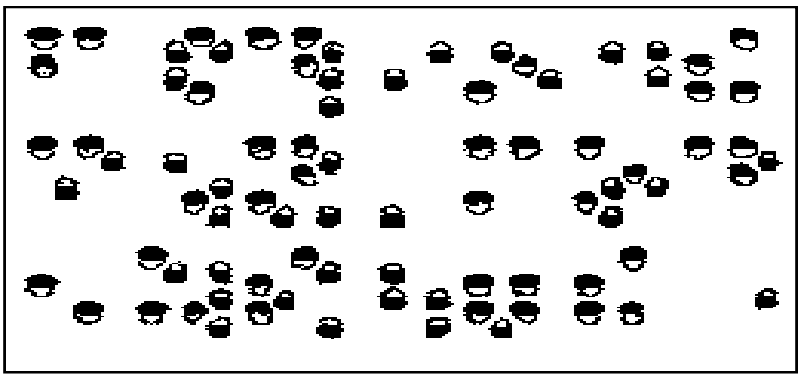

Figure 4 Result of Binarisation

2.5 Feature extraction

The main function of this process is to extract the Braille dots from the binarised image. As the shape of a Braille dot is known, the boundary points of the dots can be obtained by the boundary based Chain Code algorithm [8]. The Chain Code algorithm detects the boundary coordinates of the Braille dots. As the coordinates of the dots are detected, the diameter of the dot can also be deduced. As the dots are embossed on both sides of a page, the dots on the front-face and on the back-face must be separated before further processing. Dots on the front-face are raised above the page and those on the back-face made holes on the front side. These convex and concave characteristics of the dots reflect the illumination light in two different angles, creating an illuminated hole on the top half of the captured dot image for those front-faced Braille dots and at the bottom half for those back-faced dots. Using these illumination characteristics, the position of the illuminated hole can be used as the feature to distinguish the front-faced and back-faced dots.

Based on the boundary coordinates information and the illumination characteristics, two standard templates were constructed to represent the front-face dots and the back-face dots. The templates were then applied to every position of the image and evaluate the correlation at each pixel position. Depend on the correlation values, the front-faced and the back-faced dots are extracted.

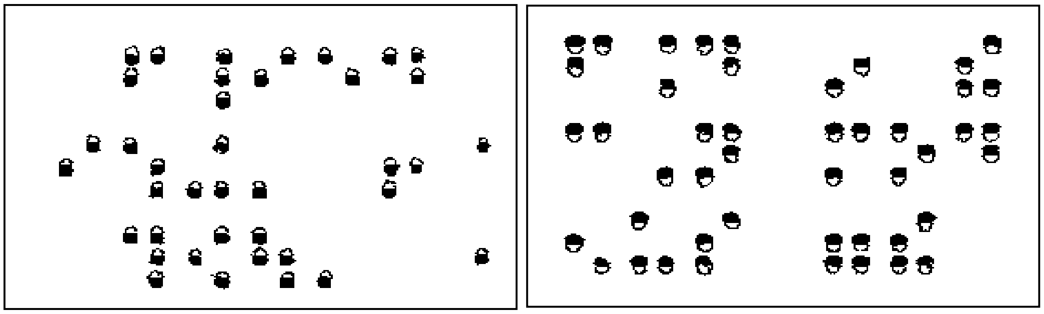

Figure 5 Result of front-faced/back-faced dots separation. Front-face dots (left), Back-faced dots (right)

2.6 Interpretation

At this stage, an orthogonal, binary image without noise is obtained. The work of this phase is to group the Braille dots into cells and converts them into their English correspondences. For each dot, the distance between the centriod and the four possible neighbours are determined. From this information, the dots are grouped into cells. Within each cell, the dot pattern is also determined and represented by a bit string. The bit strings of the cells are searched against the Braille dictionary, and the retrieved characters are grouped into words. Each word is then check against an English dictionary. If the word cannot be found, then the word with the highest percentage of similarity will be selected and will be highlighted for later edition.

3 Results and Conclusion

Using both single-sided and double-sided Braille pages as the specimen, the system has been proved to be 100% and 97% accurate respectively. The system takes advantage of the regular spacing between Braille dots within a cell, and the regular spacing between cells. The system can be used to recognition both single and double-sided Braille pages, the Braille documents can then be translated into English for further editing. The Braille documents can be embossed on a range of media and with different specifications such as page size, dot size, inter Braille dot distance and, inter Braille cell distance.

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