A Low-Cost OMR Solution for Educational Applications

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Abstract

Optical Mark Recognition (OMR) is a traditional data input technique and an important human computer interaction technique which is widely used in education testing. Aimed at the drawbacks of current OMR technique, a new image-based low cost OMR technique is presented in the paper. The new technique is capable of processing thin papers and low-printing precision answer sheets. The system key techniques and relevant implementations, which include the image scan, tilt correction, scanning error correction, regional deformation correction and mark recognition, are presented. This new technique is proved robust and effective by the processing results of large amount of questionnaires.

Keywords: OMR, low-cost, image processing

1. Introduction

Optical Mark Recognition (OMR), also called "mark sensing", is a technique to sense the presence or absence of marks by recognizing their depth (darkness) on sheet [1,4]. A mark is a response position on the questionnaire sheet that is filled with pencil or ballpoint pen. The way of marking is simple to everyone and OMR device can process mark information on sheets rapidly. Thus, OMR has been widely used as a direct input device for data of censuses and surveys and is fit for handling discrete data, whose values fall into a limited number of values. In the field of education, OMR technique is often used to process objective questions in the examination, such as College Board's Scholastic Aptitude Test (SAT), the Graduate Record Examination (GRE) in the United States, and the College English Test (CET) in China.

However, there are a few distinct drawbacks which limit the application of OMR technology.

First, the questionnaire sheets which can be processed by OMR devices must be 90-110 gsm (grams per square meter, unit of paper weight [5]). Such high quality papers are much more expensive than the common plain papers (60 – 70 gsm) and general schools can not afford to use them in common exams.

Second, the high precision layout of standard questionnaire sheet is required. The questionnaire sheets must be precisely designed and printed. The printing and cutting slips need to be and ±0.2 mm or even less which can only be obtained through professional printing house [6].

Finally, OMR machine is dedicated device that can only be used to process OMR sheets. This is a burden carried by the schools.

In this paper, a low-cost OMR (LCOMR) technique is presented. Besides implementing all the functions of the traditional OMR, LCOMR supports plain sheets (70 gsm or less) and low printing quality questionnaire sheets.

2. Related work

The OMR scanners were originally developed in the 1950s with more desktop-sized models entering the marketplace in the 1970s. The original technology was called 'mark sensing' and used a series of sensing brushes in detecting graphite particles on a document that is passed through the machine. [1,2]

The OpScan 5 from National Computer Systems (NCS) offered simultaneous data transfer between a scanner and a computer with a document throughput rate of 3,000 sheets per hour. Colleges utilized OMR technology to process course evaluation forms and schedule media center materials [6].

Since 1999, more image-based OMR studies have been developed. Chinnasarn et al. [3] presented one system which was based on PC-type microcomputer and image scanner. The system operations could be distinguished into two modes: learning mode and operation mode. The data extraction from each area can be performed based on the horizontal and vertical

978-0-7695-3471-8/08 $25.00 © 2008 IEEE
DOI 10.1109/ISPA.2008.130

projections of the histogram. For the answer checking purpose, the number of black pixels in each answer block is counted, and the difference of those numbers between the input and its corresponding model, is used as decision criterion. This is the first image-based OMR technique.

Pegasus Imaging Corporation [7] presented a SDK for OMR recognition from document images. The SDK supported template recognition mode and free recognition mode. An OMR field is defined as a rectangle area containing a specified number of columns and rows of bubbles to be evaluated. The SDK can scan the region horizontally and then vertically to locate the bubbles apart from the spaces between them. Then, based on the bubble shape specified, it scans the discrete areas of the bubbles, counting dark pixels to determine which bubble areas qualify as "filled in". The Pegasus' technique can support the plain paper's printing and design, but in the application in the school, the multi-choice answer recognition success rate can not achieve the requirements of the examination.

3. System design

LCOMR is programmed using Borland Delphi 7.0. The system can be deployed on Windows operation systems such as Windows XP and Vista. Aimed at the drawbacks of traditional OMR, LCOMR has following advantages.

1. A Microsoft Word macro-based sheet design technique to simplify the design of questionnaire.
2. Low cost image-based OMR technique and the images can be obtained from any kinds of scanner.
3. Global and regional area image deformation corrections to improve the recognition precision.

As a complex procedure, LCOMR system consists of four main parts: OMR sheet design, image acquisition, deformation correction and mark recognition.

4. Questionnaire design

Most teachers in school are capable of using Microsoft Word expertly. LCOMR supports questionnaire design using Microsoft Word. And LCOMR supplies a technique to generate questionnaire automatically. This technique is based on VBA technology. The entire layout of the questionnaire (see Figure 1), including the title, the basic information region and the OMR region, can be generated by a series of pre-defined MACRO of Microsoft Word. After generating, designers can further edit and adjust the layout the template base on their requirements.

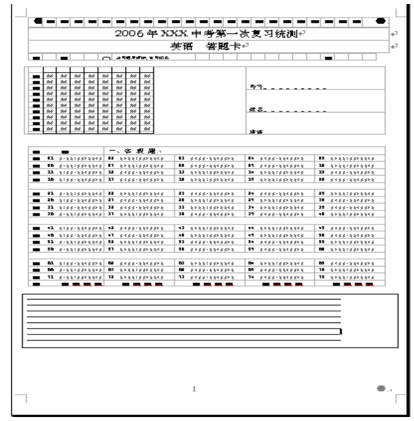


Figure 1. Layout of paper

On the questionnaire sheet, there are two types of marks: solid marks and hollow marks. The solid mark is for system usage, and we define it as system mark. The hollow mark is to be filled by students for information recognition, so is define as information mark. Moreover, solid marks are composed by two types i.e. circular-shaped and rectangular-shaped. The circular-shaped solid marks, which locate in top left and top right of the sheet, are used to correct the tilt of the whole page. The rectangular-shaped solid marks are defined as "flag points" in this paper, are used to search the coordinates of information marks. The layout of flag points appears an "L" shape and forms a two-dimension rectangular coordinate system. Each information mark has its own unique coordinate value in this coordinate system.

5. Image acquisition

In our study, high speed scanner is used to acquire the images of questionnaire sheets. Twain and ISIS scan interfaces are both supported. The average processing speed is more than 50 pages per minute. Image data are transferred from scanner to computer and stored in memory of the computer with DIB image format.

6. Image pre-processing

In traditional OMR technique, the distortion of sheet can be ignored because the sheet is thick enough to avoid the distortion when sheets pass through OMR machine. But while using plain thin sheet (70 gsm or less), the distortion of sheet becomes a critical problem in mark recognition.

The results of experiment show that there are two types of distortion which will cause OMR recognition error: global tilt distortion and scanner mechanism transmission distortion. These distortions are required to be corrected in OMR processing.

6.1. Tilt correction

Paper sheets, especially relatively thinner sheets (70 gsm or less), will be tilt when the sheets pass through scanner. Such tilt will seriously affect the precision of OMR recognition. Taking advantage of the two circular marks in the top left and top right of the questionnaire, this unwelcome effect of tilting can be rectified. Figure 2 shows the tilt angle and Equation 1 is used to calculate the tilt angle. The whole image rotate θ degrees to correct tilt error.

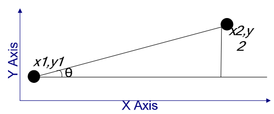


Figure 2. Tilt angle

$$\theta = \arctan[\frac{(y2-y1)}{(x2-x1)}] \qquad (1)$$

6.2. Mechanism deviation correction

The high speed scanner can produce 2D images directly. While scanning sheets (A3 or A4 size) , the scan quality and precision on x axis depends on the precision of scanner's CCD/CMOS line array and the quality and precision on y axis depends on the precision of the stepper motor and the driving mechanism of the scanner. In the study, the deviation generated by scanner is obvious and can not be ignored.

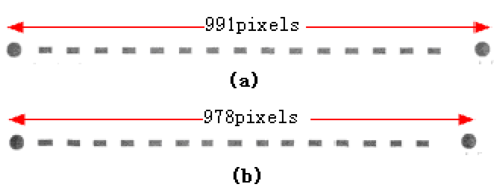
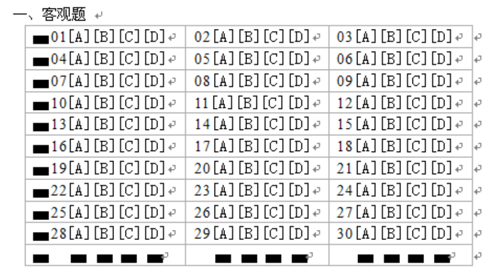


Figure 3. Scanning deviation: (a) is the firstly scanned image, (b) is the secondly scanned image

Figure 3 shows the difference of the two images of the same sheet in two times of scanning. The deviation of two images is 13 pixels. Such a deviation will lead to OMR recognition error and must be corrected. In the image processing, we calculate the scales of each axis respectively and use the scales to convert all coordinate values into a uniform system to correct such deviation errors.

6.3. Flag points searching



一、客观题

01 [A] [B] [C] [D]	02 [A] [B] [C] [D]	03 [A] [B] [C] [D]
04 [A] [B] [C] [D]	05 [A] [B] [C] [D]	06 [A] [B] [C] [D]
07 [A] [B] [C] [D]	08 [A] [B] [C] [D]	09 [A] [B] [C] [D]
10 [A] [B] [C] [D]	11 [A] [B] [C] [D]	12 [A] [B] [C] [D]
13 [A] [B] [C] [D]	14 [A] [B] [C] [D]	15 [A] [B] [C] [D]
16 [A] [B] [C] [D]	17 [A] [B] [C] [D]	18 [A] [B] [C] [D]
19 [A] [B] [C] [D]	20 [A] [B] [C] [D]	21 [A] [B] [C] [D]
22 [A] [B] [C] [D]	23 [A] [B] [C] [D]	24 [A] [B] [C] [D]
25 [A] [B] [C] [D]	26 [A] [B] [C] [D]	27 [A] [B] [C] [D]
28 [A] [B] [C] [D]	29 [A] [B] [C] [D]	30 [A] [B] [C] [D]

Figure 4. Information marks and flag points

Figure 4 shows an "L" shape coordinate system of the marks. The bottom left rectangle flag point is the origin. The recognition of the marks is to search the coordinate system and take advantage of the coordinate system to calculate the marks' values.

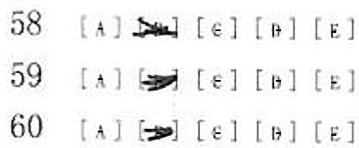
The position searching algorithm of flag points has two steps. The first step is the vertical direction searching and the second step is horizontal direction searching.

LCOMR begins the flag points searching from the pre-defined coordinate value (*x0,y0*). Commonly, the values of (x0,y0) are configured on the upward side of the top left flag point. In the searching period, the system will search a black blob within the size more than 5x5 pixels. The first found blob is the top left flag point. The centroid algorithm is used to calculate the center point of the flag point and the coordinate values are stored into the array variable FlagRowPoint[0]. This searching procedure will continue, along with vertical direction, until the final point is found. All the coordinate values are stored into array FlagRowPoint. The flag point searching on horizontal direction starts from the bottom left flag point. All the horizontal flag point coordinate values are stored into array variable FlagColumnPoint.

In the searching procedure, if the number of searched points is not equal to the known number, an exception should be generated.

6.4. Regional deformation correction.

Besides the global sheet deformation, the sheet also has regional deformation due to the influence of roll paper wheels. Figure 6a shows this kind of deformation.



(b)

Figure 5. Local paper deformation (a) and local area correction (b)

Figure 5a shows the influence of regional deformation of the sheet. The black short lines present the central position of the information marks. An obvious deviation exists between the short lines and the real center of the information marks. For example, the ordinate value of the central position of the short line on Question 60E is 7 pixels departure from the real center position.

For the purpose of reducing the effect of the regional deformation, a correction algorithm is designed. In subsection 6.3, LCOMR had searched the horizontal and vertical coordinate values of flag points and stored the values into two arrays: FlagColumnPoint and FlagColumnPoint. Through the following Equation 2, the corrected (X,Y) value of information mark is calculated:

$$\Delta x = \text{FlagRowPoint}[Y].x - \text{FlagRowPoint}[0].x$$
$$\Delta y = \text{FlagColumnPoint}[X].y - \text{FlagColumnPoint}[0].y \quad (2)$$

Figure 5b shows the corrected results of Figure 6a. The short lines locate in the center of the information marks and the results prove the correction algorithm is effective.

7. Mark recognition

After coordinate system is constructed, marks' recognition becomes an easy task. Two status of mark should be estimated, one is "filled", and another is "blank". We adopted a simple method to estimate the mark filled or not. In current system, the threshold of "filled" status is set to 0.4. It means if the cover rate is more than 40%, the mark value will be true. In a single choice question, if more than two marks are filled, the higher cover rate one will be selected as the final result.

The recognition of multi-choice OMR is difficult. In LCOMR system, all marks in which cover rate are greater than the threshold will be estimated to be "filled".

8. Discussion

For the examinees, the most significant consideration is the OMR recognition precision with plain sheet. We have processed about 200 million answer sheets based on the technique presented in this paper. The recognition success rate is always about 98% and can not achieve 100%. We analyzed carefully the reasons of errors and listed as the following:

1. Ink infiltration is the main reason of recognition error. The plain paper (70 gsm or less) is easy to be infiltrated, so the writing on the rear side will infiltrate to the front side. This will cause the error of OMR recognition. In order to guarantee 100% precise recognition, more manual works need to be performed.
2. The distortion of the thin paper is critical to affect the final recognition precision.

9. Conclusion

More than 15 schools in China have adopted this new technique. The teachers of school are capable of designing questionnaires by themselves and the supervisor of schools can adopt this technique to investigate the effect of learning and teaching easily and quickly. LCOMR partially resolves the drawbacks of traditional OMR technique and improves its usability. LCOMR is a robust and low-cost OMR technique that can be adopted widely in the developing countries.

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