An image-processing oriented optical mark reader

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ABSTRACT

This paper describes the development of an optical mark reader that can be used for counting the examination score from the multiple-choice answer sheet. The system is developed based on PC-type microcomputer connecting to an image scanner. The system operations can be distinguished into two modes: learning mode and operation mode. In the learning mode, the model corresponding to each type of answer sheet is constructed by extracting all significant horizontal and vertical lines in the blank-sheet image. Then, every possibly cross-line will be located to form rectangular area. In the operation mode, each sheet fed into the system has to be identified by matching the horizontal lines detected with every model. The data extraction from each area can be performed based on the horizontal and vertical 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. Finally, the database containing a list of subjects, students, and scores can be created. The experimental results on many styles of answer sheets show the effectiveness of such a system.

Keywords: optical mark reader, document image analysis, image segmentation

1. INTRODUCTION

Optical Mark Reader: OMR is an automatic machine for multiple choice checking system. It is very popular in used. Not only a high accuracy but also it gives a high speed for check. But we found some inflexibility of OMR. First, in each time, it can check only single answer sheet form and single subject. The OMR will check between an input answer sheet and the template answer sheet. It will reject an input sheet if differ from the template. In other word, a template form contained only one subject answer model. So if we input answer sheet with different subject from template, it will give a wrong score, some OMR machine will not check subject. Second, OMR can check only a full-fill mark in static grid position, circle or square rectangle filled by pencil, 2B or darker is recommended. From discussion above, we developed an abstraction algorithm with high efficiency and flexibility for multiple choice checking system.

Our system, an input answer sheet is scanned. The image is subjected to preprocessing step, noise reduction[1, 2] and skew detection[3]. Next, matching the horizontal line detected with every model identifies an image sheet. An information of all rectangular area in each form is read from database. Then, count the number of black pixels in Subject code area and matching subject code. Its true answer is read into list. For the answer checking process, the number of black pixels in each answer block is counted, and checking the difference of those number between the input and its corresponding model.

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2. PROJECTION PROFILE

A Projection Profile[4] is a histogram of numbers of ON-pixels accumulated along parallel rows and columns of the image. The horizontal projection profile can be applied to identify the text line in a document image by grouping the number of horizontal histogram, then classified by means threshold. In the same time, the vertical projection profile is designed for segmentation of columns in multi-column document images. Many researchers applied the horizontal and vertical projection profile to identify a character boundary. In our algorithms, the projection profile was applied to identify a circle boundary and the number of black pixels for a circle are used to be a basic criterion and stored in form library.

3. LINE CROSSING

Line is a point adjacent. For most preprinted form has many type of line in difference direction. Suppose we closed to horizontal and vertical line. Both are perpendicular together. Type of line cross is defined into 9 categories[5], such as cornerLT, cornerLB, leftT, topT, cross, bottomT, rightT, cornerRB, and cornerRT, as shown in Figure 1.

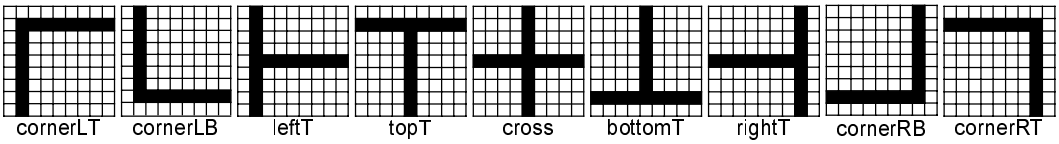


Figure 1 Cross line patterns.

Cross Line will define the rectangular field on form. This paper, the rectangular areas are classified into Subject Area Code, Student Area Code, Answer Area Code and Unused Area. For used area, in each box contain a difference number of circles. The projection profile is used to identify each circle boundary by mean threshold, and the number of black pixels is a criterion for each circle model.

4. IMAGE-PROCESSING ORIENTED OPTICAL MARK READER

The overall organization of our Image-Processing Oriented Optical Mark Reader (IPOOMR) is shown in Figure 2. IPOOMR contains 2 modes, one for learning mode. It prepares for, how to computer understand an information in each answer form. This mode compound with a form modeling for understand form type, and true answer model for a subject code in each form. The other is operation mode that deals with how to retrieve score from the input sheet.

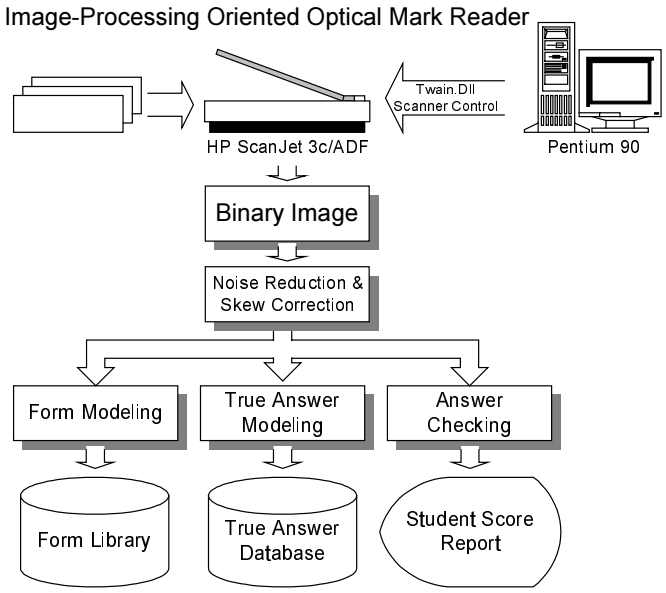


Figure 2 System overview.

4.1. Learning mode

An empty preprinted answer sheet form is entered to the system as a binary digital image by optical scanner. Again, the image was preprocessed with noise reduction and skew detection. An algorithm will search for all horizontals and vertical lines, then cross them together. Cross-Line pattern and position are kept and stored in a form library. Rectangular box coordinate, top-left and bottom-right are created from cross-line pattern and position. Each form contains 4 rectangular fields: Subject area code, Student area code, Answer areas and unused areas. A user defines field type himself. The horizontal line parameters such as amount, position, and lengths are used to identify kind of form. In this mode, we scope to model only a necessary rectangular box, subject code, student code and answer area fields

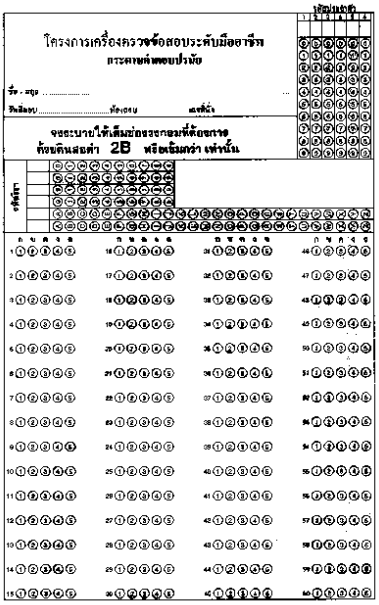


Figure 3 Input answer sheet.

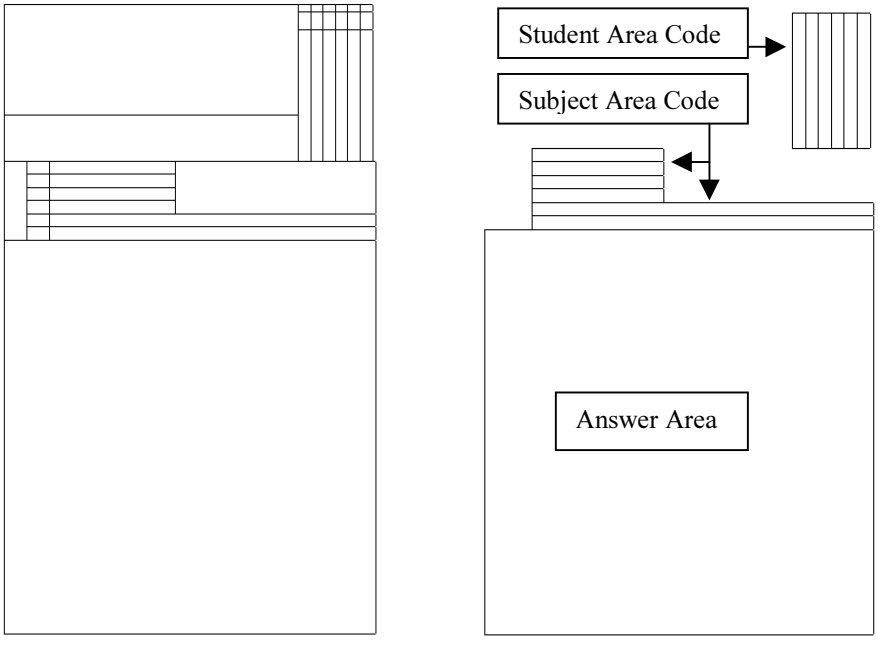
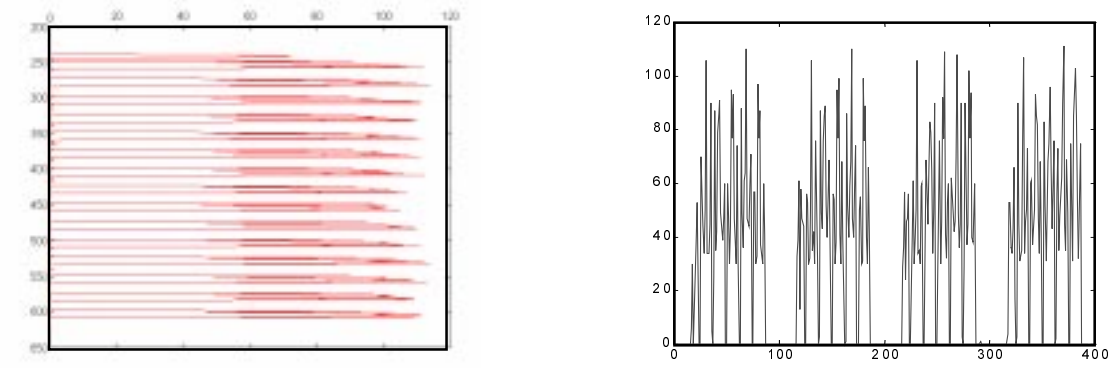


Figure 4 (a) All rectangular boxes detected. (b) Used Areas for our algorithm.

An empty answer sheet of type #1 in Figure 3 is entered into the system. All rectangular fields constructed from horizontal and vertical lines are detected and shown in Figure 4 (a). These rectangular fields have to be interactively marked by the user as Subject code area, Student code area, and Answer area, as illustrated in Figure 4 (b).

The *subject code* consists of 2 alphabets (A-Z) followed by 4 digits (0-9). Both are arranged in horizontal direction. So the vertical projection profile is used to identify each circle boundary in each field, left most and right most by means threshold. Then kept the number of black pixels in each circle. The *student code* is a sequence of 6 digits, and arranged in vertical direction. Horizontal projection profile and means thresholds are used to identify all fields' information. Thus each circle information are top, bottom, and the number of black pixels. The *answer area* contains the number of answer item or individual answer record. The vertical and horizontal projection profiles of the answer area in the sheet of Figure 3 are shown in Figure 5 (a) and (b) respectively. Total 15 peaks in horizontal direction and 4 valley in vertical direction can be counted, which results in 60 answer items (Figure 6). Again, with each answer item, it is entered to vertical projection profile for identified its boundaries, left and right. The number of black pixels is counted. Finally all information are stored into form library.



(a) (b)

Figure 5 Projection profiles of the answer area in the sheet of Figure 3. (a) Horizontal projection. (b) Vertical projection.

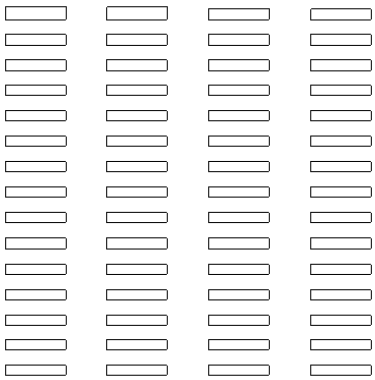


Figure 6 Answer items located from the relation between horizontal and vertical projection.

Not only form models are constructed, but also the true answer item database is an importance information for answer check. To do in this process we started with a binary digital image of true answer sheet, enter to the preprocessing system. Second, input form type is checked by horizontal line. If found, read all entries information into list. Next, separate to 2 parallel operations, subject code detection and true answer item detection. In both operations, we counted the number of black pixels within each circle, and the filled information can be extracted by the positions of maxima.

4.2. Operation mode

In this mode, the type of each answer sheet has to be identified after preprocessing. The number of black pixels in each circle boundary is counted. The next 2 parallel processes are subject code detection and student code detection. The subject code detection process, in each field search for a position of a circle contains the maximal number of black pixels. Then represent a circle position by a code discussed above. After joined the sequence of subject code, search for all information from form library and put them into lists. For student code applied a vertical projection profile and means threshold for segments a circle boundary in each field. Each Student code is created from the circle's position with the maximum number of black pixels.

For the answer check process, the number of black pixels in each circle boundary is counted and searches for the maximum value position. For each answer item, the maximum value position is compared with true answer item model, in list. If, both are the same position given point, else skip to next answer item until end list. But some students sometime marked or fill in two or more circle in each answer item. Our algorithm can protect. We do that, not only the maximum value position is checked with a model, but also it will be checked with the 2nd maximum value position of the same answer item. If their value is differing less than 15 pixels, circle boundaries 10x10 pixels, skip to next answer item.

In Figure 7, the answer sheet was marked for student code 012345 and subject code MA0496. Cross-Marks are used for the answer checking. Subject and Student code are detected and the results are shown in Table 1 and 2 respectively. Table 3 shows the detail and summary output from the answer check process.

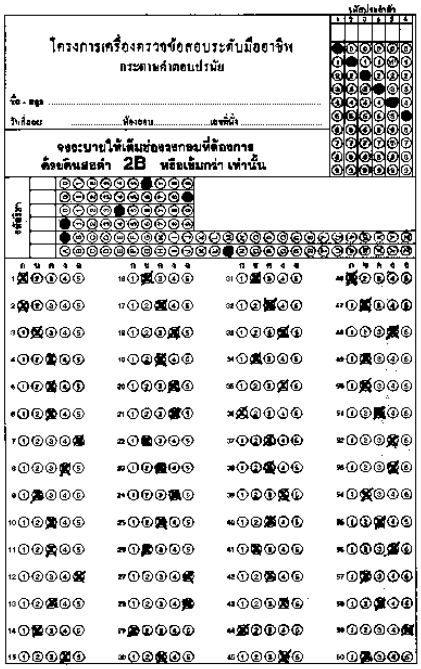


Figure 7 Input answer sheet.

Table 1 Number of black pixels in circle for subject code field, marked as MA0496.

Field No.	Number of Black Pixels
6	39 39 41 46 36 45 **98** 45 48 52
5	48 35 46 40 45 44 55 43 55 **83**
4	33 31 32 34 **84** 40 43 44 45 48
3	**77** 30 45 37 39 36 47 39 47 42
2	**80** 37 34 38 34 34 39 49 34 44 43 41 51 49 51 **48** 51 50 54 44 45 40 57 43 42 57
1	40 37 40 38 42 40 45 39 44 41 51 45 **91** 47 57 50 56 49 58 53 50 53 58 56 51 57

Table 2 Number of black pixels in circle for student code field, marked as 012345.

Field No.	Number of Black Pixels
1	**104** 62 70 72 70 59 64 54 59 58
2	61 **96** 64 64 67 75 60 54 58 56
3	67 51 **96** 65 63 71 73 72 75 75
4	61 38 40 **90** 42 46 52 45 56 56
5	73 62 61 54 **107** 58 64 60 65 61
6	63 43 37 49 50 **89** 50 45 49 46

Table 3 Details and summary output from the answer check process.

Answer Item	True Answer Model Position	Number of black pixels in each answer item from input sheet	Result
Record No. 1	**1 = 85** point	**[1,81]** [2,59] [3,45] [4,44] [5,36]	Correct Answer
Record No. 2	**2 = 85** point	[1,35] **[2,90]** [3,40] [4,42] [5,37]	Correct Answer
Record No. 3	**2 = 86** point	[1,37] **[2,88]** [3,49] [4,43] [5,51]	Correct Answer
Record No. 4	**1 = 90** point	**[1,102]** [2,51] [3,54] [4,57] [5,61]	Correct Answer
|	|	|	|
|	|	|	|
Record No. 57	**4 = 98** point	[1,40] [2,48] [3,49] **[4,82]** [5,43]	Correct Answer
Record No. 58	**3 = 97** point	[1,42] [2,52] **[3,90]** [4,50] [5,38]	Correct Answer
Record No. 59	**4 = 96** point	[1,38] [2,43] [3,45] **[4,92]** [5,41]	Correct Answer
Record No. 60	**2 = 98** point	[1,41] **[2,95]** [3,53] [4,65] [5,52]	Correct Answer
Subject Code: MA0496.F1 Student Id Code: 012345 From 60 Choices: Correct 49, Wrong 11			

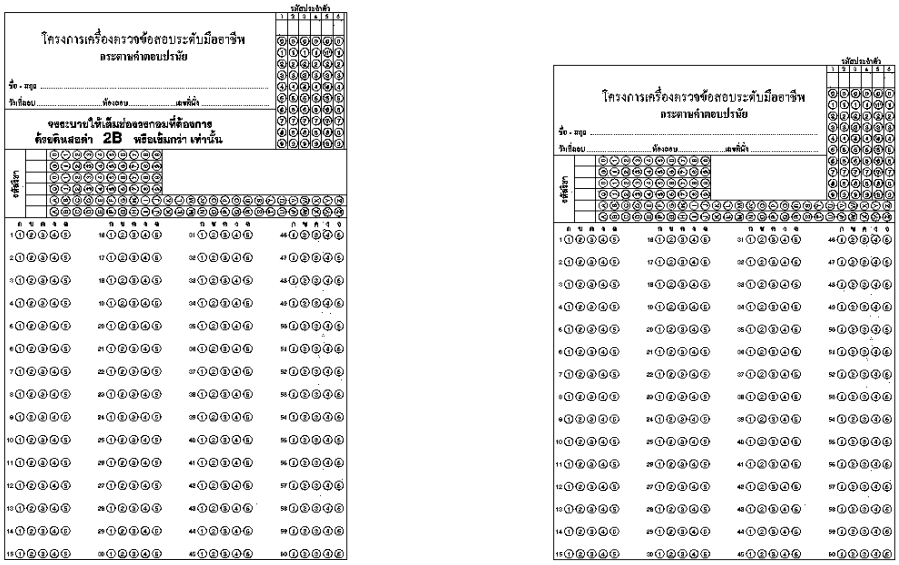
In this research, the binary image is scanned with resolution 75 dpi, with 2 types of similar answer sheets, as shown in Figure 8, were tested. The system was implemented by using a HP ScanJet/ADF scanner, connect to PC-Pentium 100 MHz with 16 MB RAM. The experiments were carried out on 30 different answer sheets for each type, with a variety of subject and student codes. The processing time and accuracy are shown in Table 4 and 5 respectively.

Table 4 Average processing time.

Answer Sheet Form Type	Average Time (Second)			
	Scanned	Model Construction	True Answer Item Model	Answer Checking
Type #1	41.442	48.727	1.131	1.300
Type #2	41.032	43.131	1.071	1.190

Table 5 Accuracy of answer checking tested on 120 images.

Pencil marked		Pen marked	
Cross or Mark	Fill-in	Cross or Mark	Fill-in
96.2%	100.0%	98.0%	100.0%



(a) Form Type #1 (b) Form Type #2

Figure 8 Two types of answer sheets used in the experimentation.

5. CONCLUSION

We have presented the development of an Image-Processing Oriented Optical Mark Reader that can be used for counting the examination score from the multiple-choice answer sheets. The system operations can be distinguished into 2 modes: learning mode and operation mode. The processing time in the operation mode depends on the complexity of each form type, 1.30 and 1.19 seconds for the answer sheet Type #1 and #2 respectively. Filling with pen gives higher accuracy than pencil for both mark and cross, because auto-detect mean threshold is used for all scans.

6. REFERENCES

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