Automated Scoring System for Multiple Choice Test with Quick Feedback

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***Abstract*—Although automatic scoring systems for multiple choice questions already exist, they are still restrictive and use specialised and expensive tools. In this paper, an automated scoring system is proposed to reduce the cost and processing restrictions by taking advantage of image processing technology. The proposed method enables the user to print the answer sheets and subsequently scan them by an off-the-shelf scanner. In addition, a personal computer can process all the scanned sheets automatically. After scoring, the proposed system annotates the sheets with feedback and send them back to students via email. Moreover, two novel features are introduced. The first feature is the handwriting recognition method to recognize student ID. We called this the segmented handwritten character recognition. This new method replaces the conventional student ID recognition commonly known as the Matrix Identifier. The second feature is our specially designed answer sheet that allows students to easily change their answers with multiple attempts. As a result, there is no need to erase pencil shading or change the entire answer sheet if any mistake happened during the test. The proposed system is designed to be cheap and fast.**

***Index Terms*—OMR, OCR, MCQ, assessment, scoring systems, answer sheets.**

I. Introduction

Technology has enhanced many aspects of the education experiences. Assessment is one of the education experiences where technological efforts have enabled us to carry this out with much more efficiency and accuracy. Nowadays, we have a myriad of technological tools to help us generate, conduct and mark assessments.

The multiple choice questions (MCQ) is a form of assessment that has been widely used in schools and universities because it can reduce the marking time by a great deal [1]. The idea of MCQ first came about by Frederick J. Kelly as a quick and effective way to discover the US talented recruits of World War I in 1914 [2]. Although the use of MCQ-based examinations is increasing in educational assessment, they can be less accurate in measuring student learning than the written-answers-based examinations. Nevertheless, many assessors prefer MCQ examinations for several reasons, and the main one being the ease of marking. This form of assessment can be marked easily and therefore it reduces the marking time for the assessor [2].

We can use some technological tools to streamline the marking process further. For example, we can conduct a computer-based test or use a MCQ scoring machine for a paper-based test. However, there are still debates about utilizing computers over the traditional paper-based tests due to (a) the logistic cost of running the computer-based test especially for a large number of students (e.g. greater than 100) and (b) the reliability of computers (i.e. not having any hardware or software issues during the test) [3]. On the other hand, the use of the MCQ scoring machines for paper-based tests are very popular due to their high marking speed and accuracy. The traditional paper-based MCQ tests are more reliable although computer-based tests still exist in most educational institutes but for a small number of students [4]. Therefore, this raises the attention of researchers to improve the traditional MCQ test by taking advantage of computer technology and at the same time keeping the paper-based test. This can be achieved by implementing a reliable automated MCQ scoring system. The idea of an automated MCQ scoring system is to recognize a customized answer sheet and then compare it with the key answer sheet to obtain the total mark. This system is by far the trade-off to mark a large number of exam papers due to the computer-based disadvantages [5].

In this paper, we aim to design and implement a multiple choice answer sheet and a reliable image processing based optical mark recognition system that can mark printed answer sheets and send back the marked answer sheets to students automatically. The purpose of the proposed system is to score a large number of scanned answer sheets and provide a quick feedback in a short amount of time.

This paper seeks to add improvements to the existing systems. To replace the conventional method of student ID recognition (matrix identifier), we propose a novel method to recognize student IDs which is called segmented handwritten optical character recognition. This technique relies on handwriting in designated segments instead of shading. Furthermore, as most of the existing solutions do not provide the ability to change answers on answer sheets and if so, the method is not intuitive for students, we propose a simple changing answer method that allows students to change answers multiple times. The proposed system will be built to provide students a quick feedback about test results. This is achieved by annotating the marked sheets and sending them back to students via student's emails.

The organization of this paper is as follows. After the introduction, the related works are discussed in Section II. Section III explains the proposed system while the experimental results can be found in Section IV. Lastly, the conclusion and the future work are presented in Section V.

II. Related Works

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IBM developed the first commercial test scoring machine which is called IBM 805 Test Scoring Machine in 1937 [6]. It was a breakthrough in educational technology. The machine reads the pencil marks by sensing the pencil lead as lead makes connectivity when it exposed to electrical to charges through the contacts plates. There is a "scoring key" to determine the right and the wrong answers based on the connectivity of the shaded answer. Then, the machine shows the total score via an inductor. The machine needs a human intervention, as it cannot score multiple test cards (answer sheets) automatically. Later in the beginning of 1960s, IBM 805 Test Scoring Machine was replaced by a new technology called optical mark recognition (IBM 1230) [7]. IBM implemented the first optical mark recognition which was designed successfully by Everett Franklin Lindquist. Lindquist's mechanism is that the acquired marks are contrasted by a light beam at the mark positions of the answer sheet to recognize the selected choice. The machine recognizes the shaded mark as it reflects less light compared the unshaded mark on the answer sheet [8]. This concept is shown in Fig. 1.

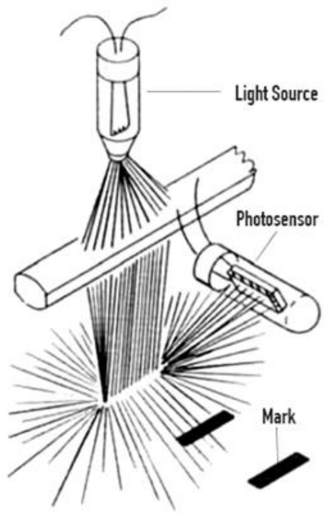

Fig. 1. Photoelectric conversion unit of IBM 1230, which contains a light source to emit light and a photo sensor to detect the reflected light [12].

Nowadays, there are several other corporations that provide scoring machines, such as Scantron. Scantron Corporation is the recent leading company in optical marks recognition machines [9]. Although Scantron optical readers carry the same idea of IBM optical mark recognition machines concept, Scantron's optical mark recognition system was patented. What makes Scantron Corporation special is that it focuses on providing a range of optical mark readers to educational institutions [9]. Scantron claims that it serves 98% of the best American schools and 94 universities of the best universities in America, and their products are utilized in different 56 countries across the globe. Scantron claims that the growth in the demand of Scantron' products shows that Scantron optical mark recognition solutions are reliable for the assessors [10].

However, despite the fact that they have a high reliability in some institutions, the cost of their products and their maintenance is very high, especially for small scale institutes. The cost of Scantron machines varies depending on the machine model. The prices of their machines range from USD 5,400 to USD 17,275 [11]. In addition to the high cost machines, the existing scoring machines require specialized answer sheets (transoptic papers), which cost USD 0.15 for each, and limited pen's colors.

In the last two decades, an effective alternative method which is based on image processing technology has developed a PC-based optical mark recognition system to reduce the restrictions of such scoring machines. According to Sandhu, Singla, and Gupta [13], region symbol and optical character recognition were the base to achieve a new method of optical mark recognition system for an automated multiple choice test. The new solution aims for a cost effective and fast optical mark recognition system with customizable answer sheet.

In 1999, Chinnasarn and Rangsanseri [4] developed the first PC-based marking system which reads printable answer sheets from an ordinary optical scanner. An empty answer sheet has to be read first as learning model to recognize the interest areas such as unit and student code. Later, in operation model, a set of answer sheets are processed based on an answer model.

Nguyen et al [14] developed a reliable algorithm to use camera instead of an optical scanner as they aimed to simplify multiple choice questions marking. It is justified that acquiring answer sheets via a camera is faster and more portable than an optical scanner. Furthermore, in size-wise, a camera is portable which is better for mobility when it is compared with a normal scanner size.

Čupić [15] developed an open source Java based marking system. The offline application is designed to mark two sets of test answer sheets; classical multiple-choice tests which offer multiple choices without test questions in the sheets and integrated test and answers sheets which offer both but with less number of multiple choice questions. The application offers different kind of information recognition for student ID and unit code such as barcode and matrix. Čupić et al [16] carried out with more emphasis on student ID identifier matrix in the same answer sheets to achieve a 100% recognition rate with the presence of high rotation and skewing. Furthermore, Bonačić et al [17] continued Čupić's research on information decoding for student ID by introducing an optical character recognition of seven–segment display digits. A template of a 7-segment display for each digit is designed for students to shade. The locations of digits and digit segments (areas of interest) are predefined to recognize the numbers from 0 to 9 based on the input patterns. Although the method seems to be restrictive and based on shading instead of handwriting, it is more intuitive and easier than identifier matrix for students to encode as shown in results of over 90% success rate. Moreover, Čupić *et al*. [18] devised a method for students to change their answers for a second or third time if answered wrongly. If students alter their answer, they can simply annotate the error with a circle and write the correct letter next to the answer area. Later, while processing, if the error circle is shaded, the handwritten character is recognized whether it is A, B, C, E, or F character.

Sattayakawee [19] proposed three versions of grid based answer sheets that delivered an average accuracy of 99.9%. Her method relied on tick marks as opposed to the complete shading of the answer boxes.

Finally, Chai [20] designed an automated marking algorithm which emphasizes more on result feedback. The proposed method marks printed answer sheets and annotates the scanned sheets by highlighting the correct and wrong answers next to each answer and send the annotated sheets back to student via email. The results show that the method is quick with up to 1.4 seconds per sheet and accurate.

III. Proposed Method

From the review of the related works, it appears that most of the implemented algorithms focus only on one aspect of test scoring which is mark registration and detection. However, student ID and name recognition is also a vital aspect to focus on because if a student data was not decoded right, there is no point of the scored marks. In this paper, we put an emphasis on both aspects (student's ID and marks) in a novel methodology.

The proposed system is investigated to reach the objectives. The proposed system is based on image processing technique. An overview of the answer sheet design is illustrated in Fig. 2, which shows the different sections of the answer sheet. As illustrated in Fig. 2, the proposed answer sheet is composed of five sections, which are student ID, instruction, exam information, answer area, and finder pattern area. The main sections for the system to recognize are finder pattern, student ID, and answer area. In addition, Fig. 3 shows the actual answer sheet design. The proposed answer sheet is designed to have 72 answer item with five choices in each. The overview of the proposed approach is depicted in Fig. 4. To start scoring, answer key and student database which includes students' ID and emails are required. The proposed approach starts by scanning answer sheets via an optical scanner. The proposed system adopts an optical scanner over camera. The reason is that scanners can be used to scan a large number of answer sheets with a better quality and less noise and distortions. However, the scanned answer sheet is usually subjected to noise, tilt, and contrast issues, hence a noise removal and brightness adjustments are needed before the next processing stage. Next, the answer sheet needs to be registered. The aim of the registration is to find the three finder pattern points. If they are located, a tilt adjustment is made to straighten the answer sheet. After adjusting the answer sheet, student ID and answer area are segmented to recognize whose paper it is and what a student score is. After segmentation as shown in Fig. 4, the proposed method will execute an optical mark recognition algorithm to detect marks in answer area as well as a student ID recognition algorithm to recognize the handwritten student ID. After decoding student ID and scoring answer area based on the key answer correctly, the scored answer sheet will be annotated to show the correct and wrong answers with total score. Furthermore, a spreadsheet will be generated which lists each recognized student ID with its corresponding score. As shown in Fig. 4, the same process will be repeated until the last scanned answer sheet in the specified directory. Finally, after processing all answer sheets, the annotated answer sheets will be sent to student via email. As the system is designed mainly to segment and decode handwritten student ID and marks, the technical details of the finder pattern, student ID, optical mark recognition algorithms will be explained.

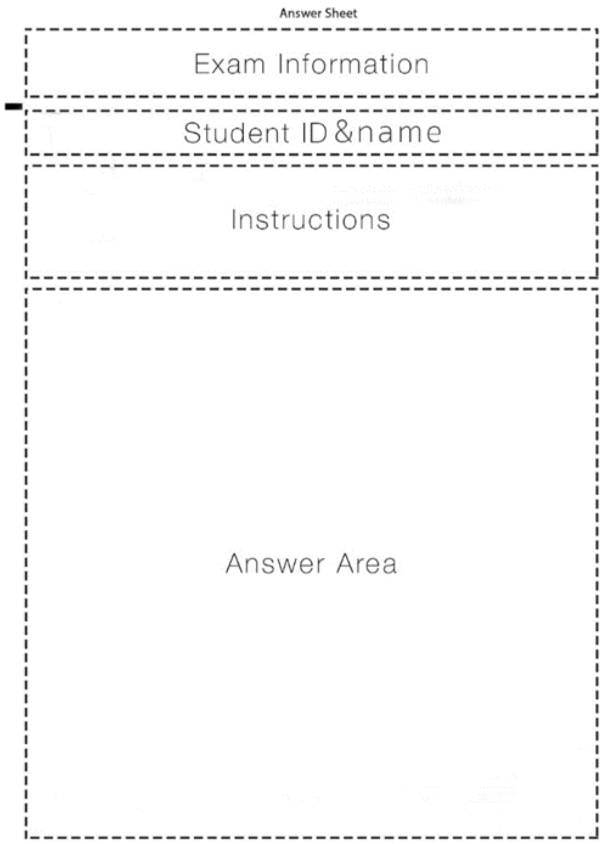

Fig. 2. The proposed answer sheet sections.

A. Finder Pattern Recognition

Recognizing the three points that make up the finder pattern (see Fig. 2) is very crucial. The answer sheet has to go through enhancements to make it ready for recognition. Firstly, the answer sheet is converted into grayscale and then binarized by a threshold. This includes filtering noise and small objects in the answer sheet margin (finder pattern area) which its size is smaller than the size of the finder pattern point. Next, as the size of the finder pattern points are known, every pixel group that is greater and smaller than the points size is eroded. Therefore, we are left up with objects (pixel groups) that have similar size as the points size which are supposedly three pixel groups. Now, the centroids of the three pixel groups are calculated. Therefore, points 1, 2, and 3 are recognized by the following equations:

$$P_1(x,y)=\min(k(y)) \quad (1)$$

$$P_3=\max(k(x)) \quad (2)$$

$$[P_2(x,y)>P_1(y))]\cap[P_2(x,y)<P_3(x)] \quad (3)$$

where $P_{n(\ldots)}$ is the centroid of the finder pattern point which has x and y value and k is a 2×3 centroid matrix of the three points after the binarization, i.e.

$$k=\begin{bmatrix} x_1\ x_2\ x_3 \\ y_1\ y_2\ y_3 \end{bmatrix}. \quad (4)$$

Equation 1 shows that point 1 is the closest pixel group to the reference point in both axes. Moreover, point 3 is located in the furthest location in x and y axis. Lastly, after locating points 1 and 3, point 2 must be greater than point 1 with respect to y and less than point 3 with respect to x.

The answer sheets are usually not scanned precisely straight. As a result, each of the scanned images will exhibit a small angle of rotation. As shown in Fig. 2, points 1 and 2 on the left side of the answer sheet are located in the same column. Therefore, as the location of both points are recognized, if there is a tilt, the angle of rotation between the two points can be estimated by

$$\theta = \tan^{-1}\left[\frac{P_{1(y)} - P_{2(y)}}{P_{1(x)} - P_{2(x)}}\right] \quad (5)$$

where θ is the angle of rotation and $P_{n(...)}$ is the centroid of the finder pattern point with respect to x or y. Now, the image can be straightened by rotating the image by the same degree of rotation in the opposite direction.

After the process of recognizing the finder pattern is achieved, the student ID and the answer area can be segmented. This is because the space ratios between the points and student ID and answer area are pre-calculated. Now, every section of the answer sheet can be processed separately.

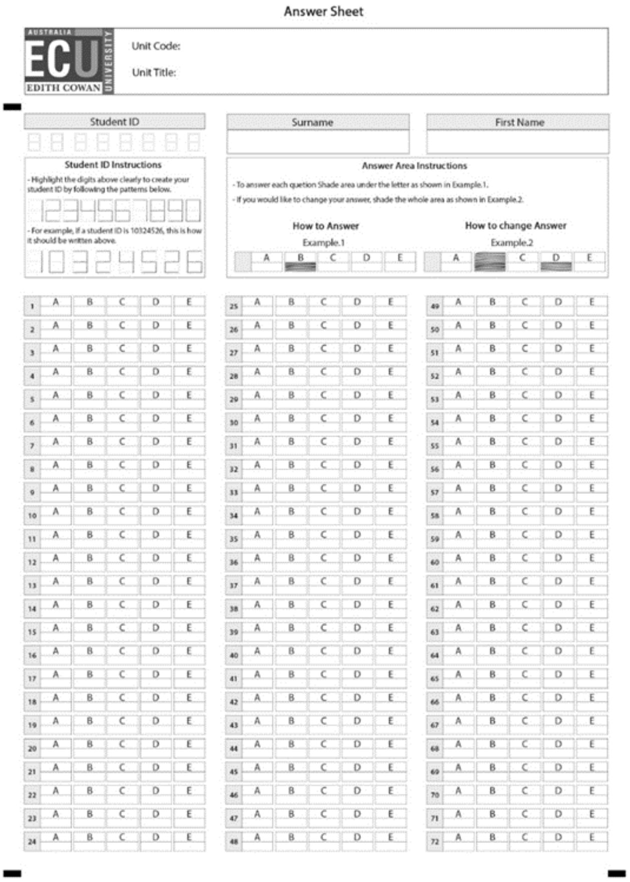

Fig. 3. The proposed answer sheet design.

B. Student ID Recognition

Student ID is the only unique identity for every student, hence the only way to recognize a test taker is by decoding the ID on the answer sheet. The recognition process is devised to make student ID encoding much more intuitive than the conventional method of most existing solutions (matrix identifier). However, as every student has a different handwriting style, it is difficult to recognize every student ID correctly. In this method, students have to write their IDs in segmented digits. In this way, the possibility of facing irregular character shape is less and the chances of writing style are limited.

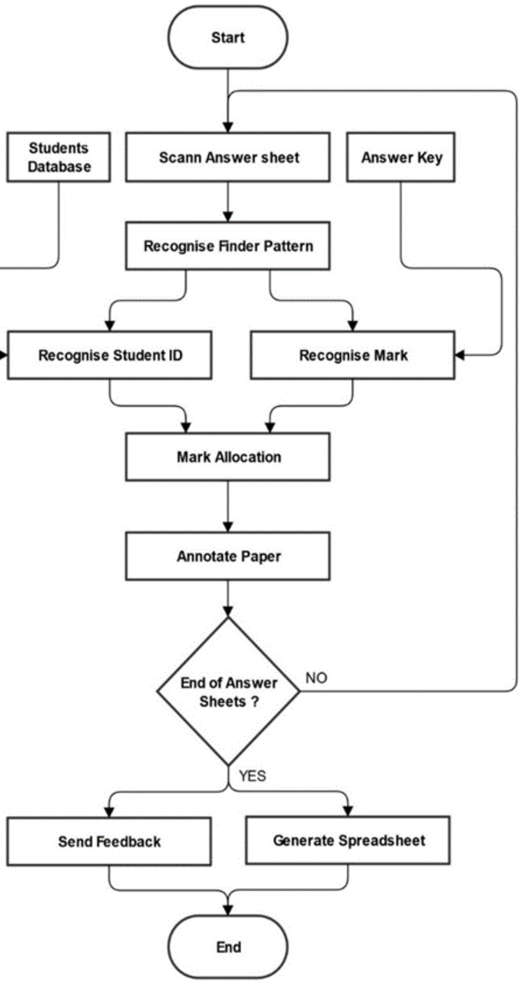

Fig. 4. Flow chart of the proposed system.

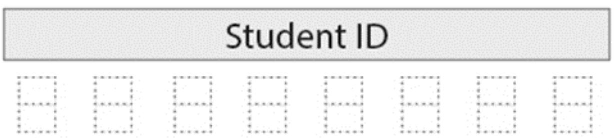

Fig. 5. Student ID area design.

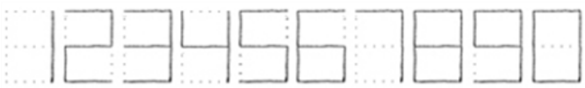

Fig. 6. The style of the handwriting of all ten digits.

Fig. 5 shows the design of student ID area which consists of eight segmented characters. In every character area, a template shows the segments pattern of how the character should be written on the dotted lines. The algorithm is designed to interpret the numbers from zero to nine. Fig. 6 shows the style of the handwriting of each number which indicates how easy to write a number. Students do not have to create strictly a straight line as shown in Fig. 6. The algorithm is designed to be more flexible with curves if they are within the region of interests (segments) as indicated in Fig. 7 in the seven blue areas. The algorithm starts by binarizing and thinning (pre-processing) the characters to remove noise and the dotted lines. The aim is to retain only the connected pixel components. Then, there is a calculated threshold of pixel numbers for every segment. If the number of pixels reaches the threshold, the segment is decoded as an active segment. After decoding every segment of a digit, the registered segments are multiplexed into a decimal number. Finally, the decoded ID is checked with student database. If the decoded ID does not exist in the database, the ID and the scored mark are saved with a note to be reviewed by the user. This process is repeated for the rest of the digits. An example of number two recognition is illustrated in Fig. 8. Further experiments on the robustness of the algorithm will be discussed in experimental results and discussion section.

C. Mark Recognition

Recognizing optical marks is the core of the system. The proposed answer item is designed to handle five alternatives as shown in Fig. 9. In addition, the proposed optical mark recognition is designed to allow students to change their answers without a need to use a pencil and an eraser. To change an answer, student needs to shade the area above the answer area and attempt again as shown in Fig. 10(d). Therefore, the algorithm is designed to analyze the marks within these four possible cases for each answer item: no entry, single entry, multiple entries, and single entry with changing answer attempt as shown in Fig. 10.

After locating the first answer item, every choice area is checked based on a threshold. If a shaded area is detected, the area above the choice (changing answer area) is checked. If the changing answer area is not shaded, the choice will be compared with answer key. Based on the answer key, the mark will be scored or not. However, if both answer and changing answer area are shaded as shown in Fig. 10(d), the mark will be ignored and the adjacent choice will be checked until the another mark is detected or until the end of the fifth choice is reached. The same steps will be repeated for the rest of the answer item until the end of MCQ and the total score will be computed.

D. Score Feedback

The final step of the system is to provide a feedback about the test. After scoring all MCQs, the locations of the detected marks are stored to be annotated as shown in Fig. 11(a). As illustrated in Fig. 11(b), the shaded areas are highlighted based the answer key. If the answer is correct, the area is highlighted green. In addition, if the answer is wrong, the area is highlighted red and corrected answer is highlighted blue. Finally, after scoring and annotating all answer sheets, the user has the option to check the results and send all sheets to students via email.

IV. Experimental Results

The proposed system was implemented in Matlab programming language. The system was tested on a MAC operating system, computer powered by Intel Core i7 processor with 8GB RAM. Instead of using separate printer, photocopier, and optical scanner, a multifunction device which contains all of them, was used for system testing. The multifunction's model is Ricoh Aficio MP C5501A. The device can print 55 answer sheets in a minute. Moreover, it can scan multiple answer sheets at once automatically from the scanning tray, not like the ordinary scanner where the user has to scan all answer sheets individually.

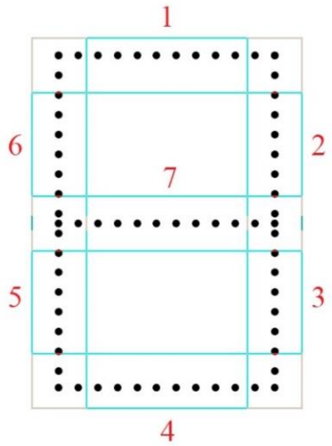

Fig. 7. The seven segments active areas.

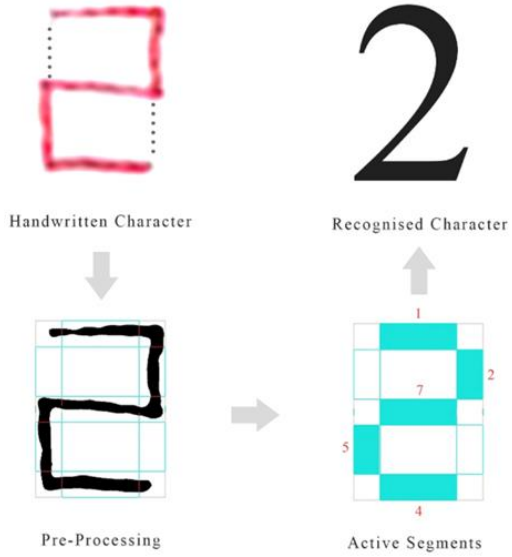

Fig. 8. An example of handwritten number recognition.

In the first place experiments were made before the real exam situation. The experiments aim to measure the system's speed, accuracy, and robustness. Firstly, the average processing speed will be discussed. Secondly, the robustness of finder pattern will be tested based on the rotation angle. Later, Student ID recognition accuracy will be experimented with different writing styles. Finally, multiple shading style with different colors contrast will be tested to verify precision in mark recognition.

We evaluated the proposed system in an in-class MCQ assessment for 88 students. The processing time of scoring 88 answer sheets is 35 seconds. This is equivalent to 0.4 second per answer sheet. This time includes scoring an answer sheet without annotation. The processing time of scoring and annotating answer sheets is 227 seconds which is equivalent to 2.27 seconds per answer sheet. This is the time from reading the image from the hard drive to saving the annotated sheet. The processing time of the system is far better than manual marking. It takes almost 7 minutes to score the same proposed answer sheet and allocate the score for each student. The average processing time of a fast optical mark machine to score an answer sheet is almost 1.4s [21]. For example, if we compare Scantron OpScan 8 which costs around USD 11,335, the proposed system is faster and much cheaper. Table I shows the comparison between manual scoring, Scantron OpScan 8, and the proposed system.

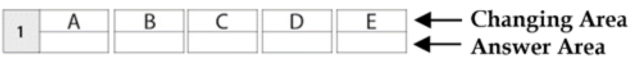

Fig. 9. The proposed answer item, which contains five alternatives.

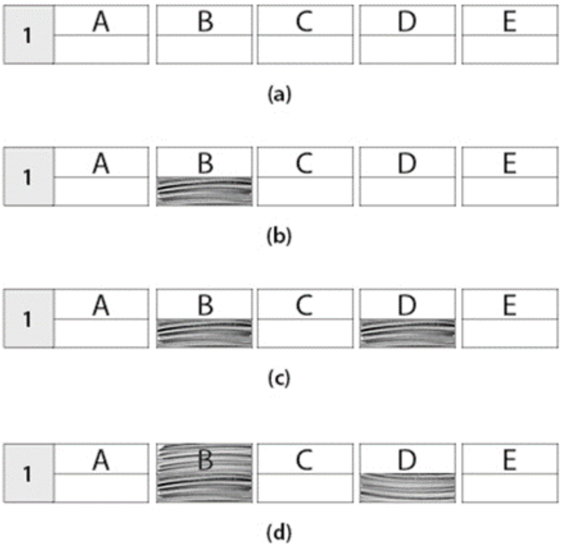

Fig. 10. The four possible cases of answering the answer item, (a) no entry, (b) single entry, (c) multiple entries, and (d) single entry with a changed answer.

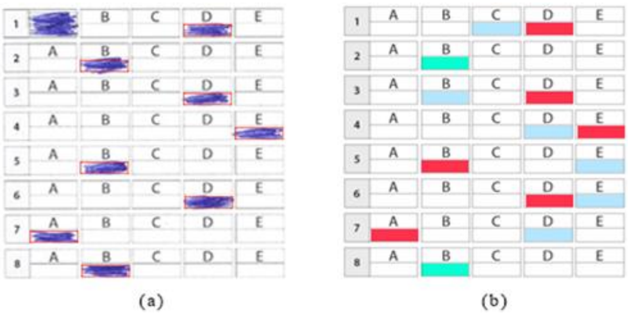

Fig. 11. The annotation style, where red color represents wrong answer, blue corrected answer and green correct answer.

As an optical scanner is required to read answer sheets, the robustness of the finder pattern detection must be tested to what extent it can be registered. The main sort of distortion that can affect the answer sheet while scanning is rotation. Furthermore, some cheap scanners exhibit noise on the edges. Therefore, in the first place, an experiment was done to test what the maximum rotation degree can be corrected and how robust the detection algorithm to erode the noise. Several rotation degrees have been tested and it was found that the maximum rotation can be corrected is 6 degrees clockwise or anticlockwise although usually the normal tilt degree is between 0.5 to 1.5 degree. Furthermore, a low quality scanner was used to test the noise removal and rotation correction. The result is shown in Fig. 12. It can be seen that image (a) is very distorted with noisy background and the answer sheet is rotated by almost 6 degrees. Moreover, image (b) illustrates the final result of image registration. It can be seen that with all that noise, the finder pattern was registered and the rotation is corrected perfectly. The success rate of image registration for the real test is 100%. All the 88 scanned answer sheet were successfully registered. This shows that the proposed finder pattern algorithm is very robust to noise and rotation errors.

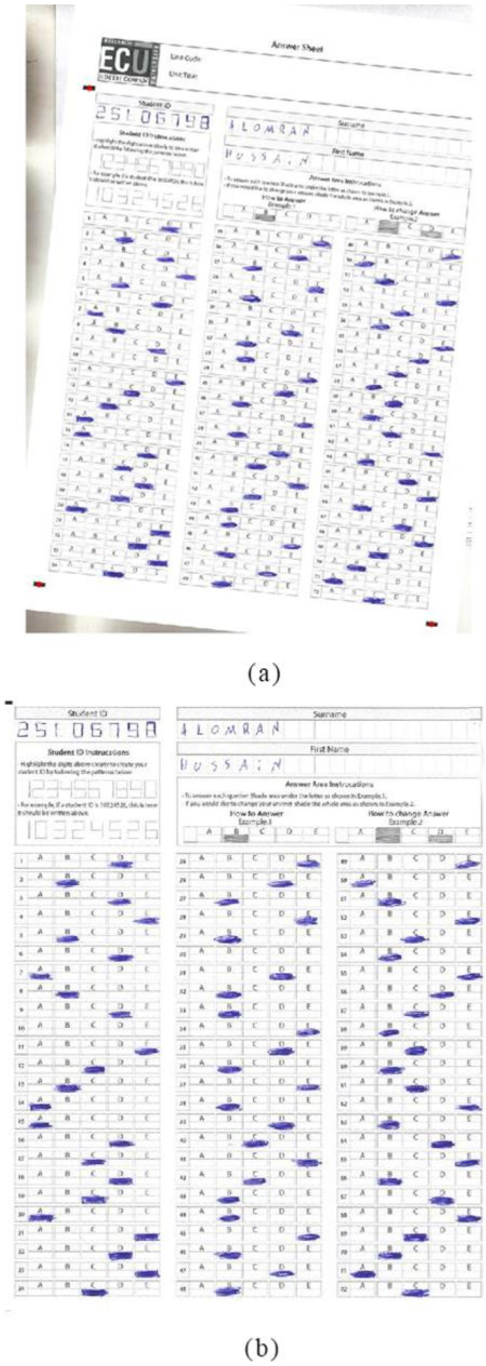

Fig. 12. An example of image registration of a distorted paper.

The segmented handwritten character recognition algorithm was tested with various styles before the real test. The algorithm proved to be accurate after testing over 100 numbers. To show a result, numbers from zero to nine were experimented as shown in Fig. 13. Every number was written eight times with different styles. Under the handwritten numbers are the recognized numbers. As shown in Fig. 13, if the numbers are written on the proper segments, the proposed algorithm will decode the number correctly. Furthermore, the numbers six and nine can be written in two different styles as shown in Fig. 13. Number one can be recognized correctly even if it is written in any side of the segment. This is because with number one, the width of the character is checked first, if the width size is less than the segment size, the number is recognized as one. The student ID recognition success rate is 95%. Fig. 14 shows some of the real test recognized student IDs.

TABLE I: SCORING METHODS COMPARISON IN TIME

Manual Scoring	OpScan 8	Proposed System
7 minutes	1.39 seconds	0.4 second

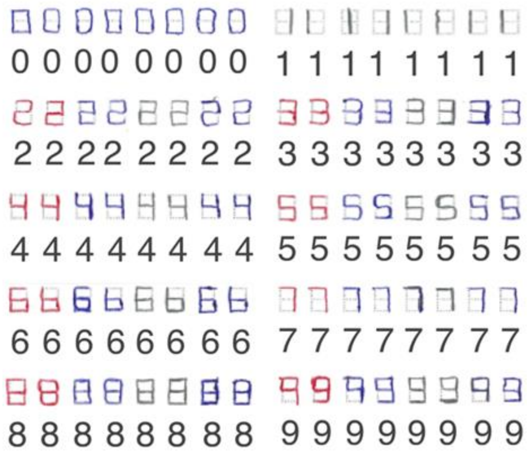

Fig. 13. Character recognition test of the ten numbers.

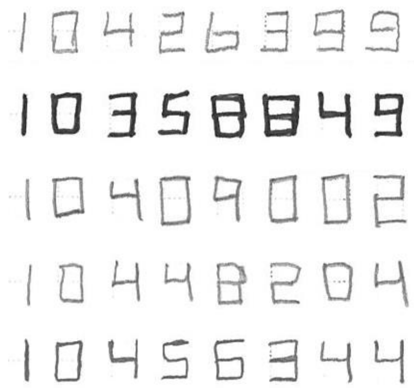
Fig. 14. An example of real test recognized student IDs.

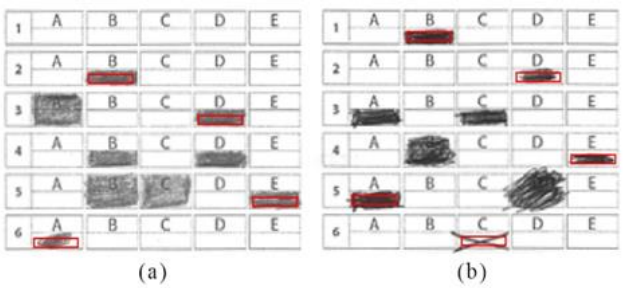

Fig. 15. An example of mark recognition cases.

As the optical mark recognition algorithm was implemented to analyze the four possible cases for each answer item: no entry, single entry, multiple entries, and single entry with changing answer attempt as shown in Fig. 10, the four cases were tested. Over a thousand marks were detected with 100% success rate for the real test. Fig. 15 shows two examples of mark recognition. As shown in Fig. 15(a), Q1 has no entry, hence no mark was detected. Furthermore, Q2 and Q6 have a single entry and it can be seen that the marks are highlighted with a red rectangle. Q3 and Q5 show a single entry with changing answer attempts. The marks are ignored because change answer areas are shaded and the marked area without changing answer attempt is registered. Moreover, the algorithm is able to recognize if there are multiple entries as shown in Q4, hence both marks are not scored. Fig. 15(b) shows another example of mark recognition. It can be seen in Q6 that any style can be recognized as long as the shape covers at least 40% of the answer area, which is the recognition threshold.

V. CONCLUSION

In this paper, an effective optical mark recognition system to score multiple choice questions is presented. The system aims to reduce the cost and time of scoring hundreds of tests papers by taking advantage of image processing algorithms.

The new contributions of this paper are: new method to provide a quick feedback to students; novel method to recognize student ID which replaces the old style of matrix identifier; allowing students to change their answers on the answer sheet with multiple attempts without changing the sheet. The experimental results show that the system has a fast rate to process answer sheets with a rate of 0.4 seconds without annotation and 2.27 second with paper annotation. In addition, the experimental results show that the system is robust to detect the finder pattern and straighten the sheet with a high level of noise. Student ID and mark recognitions proved to have a satisfactory level, which makes them reliable for exam uses. Future work will aim to improve the user experience rather than using Matlab to score. Moreover, it is aimed to make the existing system available online, hence every user across the globe can utilize the system. The user can upload the scanned sheets to a web server. Later, they will be processed and sent back to the user's email.

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