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**Research Article**

# The Use of Hough Transform to Develop an Intelligent Grading System for the Multiple Choice Exam Papers

*Hough Dönüşümü Kullanılarak Çoktan Seçmeli Sınav Kağıtları İçin Akıllı Bir Notlandırma Sisteminin Geliştirilmesi*

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## Abstract

Grading multiple choice exams are generally performed using automated systems known as optical mark recognition machines. Although such automated solutions are available in the market, there are some challenges that the educators and researchers encounter such as setting up and maintaining the system (they require a certain amount of budget) and inaccessibility of the algorithms and processes running inside the machines. A series of approaches is proposed in this study to bring a new perspective to the automatic grading systems used for the multiple choice exams. The study focuses on the use of Hough transform method. To verify the validity of the automated grading system proposed, it is tested on more than 1000 exam papers. The performance of the system is demonstrated using the results obtained the experimental studies.

**Keywords:** Automatic grading systems, Automation, Hough transform, Image processing, Multiple choice exams

## Öz

Çoktan seçmeli sınavların notlandırılması genellikle optik işaret tanımlama makinaları olarak bilinen otomatik sistemler kullanılarak yapılmaktadır. Bu tarz çözümlerin var olmasına rağmen, eğitimcilerin ve araştırmacıların karşılaştığı bazı sorunlar vardır. Eğitimciler açısından; belirli bir bütçe gerektiren sistem kurulumu ve bakımlarının yapılması, araştırmacılar açısından ise; makina içerisinde çalışan algoritmalara ulaşmanın imkansızlığı gibi zorluklar mevcuttur. Bu çalışmada, çoktan seçmeli sınav kağıtlarının notlandırılması için yeni bir bakış açısı önerilmekte ve adımları sunulmaktadır. Çalışma, Hough dönüşümü kullanımı üzerine yoğunlaşmıştır. Önerilen otomatik notlandırma sistemi, 1000'den fazla sınav kağıdı üzerinde test edilmiş ve doğrulanmıştır. Sistemin performansı yapılan deneysel çalışma sonuçları ile gösterilmektedir.

**Anahtar Kelimeler:** Otomatik notlandırma sistemleri, Otomasyon, Hough dönüşümü, Görüntü işleme, Çoktan seçmeli sınavlar

## 1. Introduction

For the last two decades, computers and computing technologies have been rapidly grown and used for automatic scoring of exam papers including multiple choice questions. The advancements of these systems are parallel to the developments in technology and have been still continuing to increase. The usage of automatic grading systems can be able to reduce the reading load of exam papers and human errors that may occur during manual grading because of tiredness, inexperience, etc. Automatic grading systems can also decrease time, cost and energy required to grade the multiple choice exam papers. The use of them affects the grading accuracy as well.

In the market, there are different types of automatic grading systems which are known as optical mark recognition machines (OMR). They have been used for grading exam papers including multiple answer choices. Although OMR machines are suitable for grading the exam papers, a budget is required for setting up and maintaining them. The algorithms running inside these machines are not also provided by the manufacturers. Due to such limitations, the researchers who wish to make a contribution on these systems could not find an opportunity.

Some automatic grading systems have been developed and presented in the literature as an alternative to the market

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solutions. They mainly focus on developing systems for detecting the objects in an exam paper and mathematical models for grading. Most of these studies have been conducted to create algorithms based on image processing techniques.

(Fisteus et al. 2013) developed a low-cost and portable grading system for multiple choice exam papers. The system performs mark and character recognition of hand written papers. (Nguyen et al. 2011) introduced an efficient and reliable camera based multiple choice test grading system. The system is based on commonly used image processing techniques. It is a low cost solution as an alternative for the conventional optical mark recognition systems which are already available in the market. (Abdu and Mokji 2012) developed an automatic grading system based on Hough transform technique. The working principle of their systems is summarized as: firstly an empty answer sheet is scanned so that the required data is stored into the computing system. Then a combination of Hough transform and region of interest algorithms are used to find the true answer regions. The system proposed strictly depends on the answer sheet's format. (Zampirolli et al. 2013) introduced an automatic correction system for multiple choice tests. The system includes a digital camera and an image processing technique. The study presents a method which is based on transforming captured images of each answer sheet into binary format. It basically follows the simple morphological operations for segmentation objective. (Rakesh et al. 2013) proposed a cost effective optical reader system. The system developed includes a scanner and a computer and uses a simple image processing algorithm. (Chinnasarn and Rangsanseri 1999) developed an image processing oriented optical mark reader. The system uses a microcomputer which is connected to a scanner. An empty answer sheet is introduced to the system and then a digital library is created. (Sattayakawee 2013) presented a study related to scoring for non-optical grid answer sheets. The system is constructed using the projection profile method and thresholding technique.

In this paper, a new approach for scoring the exam papers including multiple choice answers for each question is proposed. Adapting the Hough transform technique to develop an automatic grading system is the main focus of this study. Information on each answer sheet of the exam papers is converted to digital format so that the developed algorithm could use the digital data. Then the answer choices, which are shown by the circles (bubbles), are detected by using the Hough transform method. The automatic grading system developed is tested using more than 1000 exam papers. Each exam paper has 25 questions and each question has 5 answer options. The methodology and the experimental results are presented in this paper.

This paper is organized as follows. In Section 2 material and methods are described. The Hough transform method is also presented in this section. In Section 3 experimental results are given. The paper is concluded in Section 4 with an analysis of results.

## 2. Material and Methods

In computer vision and image processing there are number of problems frequently encountered. One of these challenging problems is to extract the desired features in an image. In an image desired objects may have different shapes that cannot be identified using regular approaches and computer programs. To solve such problems, number of solutions has been proposed. One of these solutions is the Hough transform technique that can be used to identify any objects and shapes placed in an image. It can also classify the desired objects and shapes regarding to the parameters specified to describe them.

The Hough transform technique has been commonly in use in computer vision, robot vision, automation, control and image processing applications. This technique was proposed by (Duda and Hart 1972) to find shapes and objects in an image. Originally, the technique developed could not able to detect circular shapes (Hough 1959, 1962). After some extensions have been added, the original version has evolved and is now able to detect circular objects and shapes in images.

Hough transform consists of a method that can enable to count the number of points placed on a possible line in a data set or in an image. This method focuses on representing the lines in a form which is constructed based on slope intercept information. It creates a space for the line parameters as well. In other words, the method transforms each of the possible line points into a straight line of which the parameters are located in a parameter space known as the Hough accumulator. This plane is a two dimensional slope intercept plane. The set of all straight lines in a data set composes of a slope-intercept parameter family. In this parameter family normal parameterization procedure, which is about presenting a line by vector form, enables that a single straight line can be obtained using a single point. The normal representation shown in Figure 1-a includes a straight line which makes an angle $\theta$ with its normal

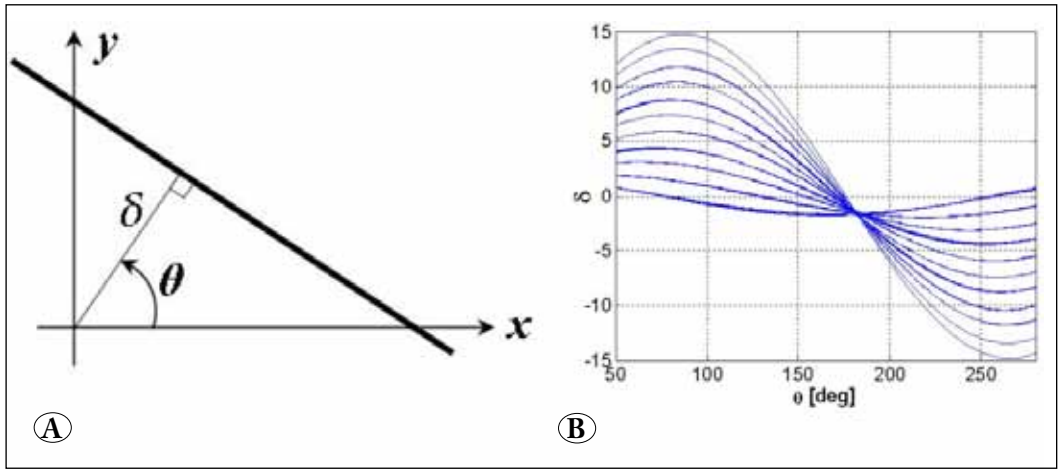


**Figure 1. (A)** A line representation with the normal parameters for the Hough transform. **(B)** Sinusoids corresponding to co-linear points intersected at a unique point.

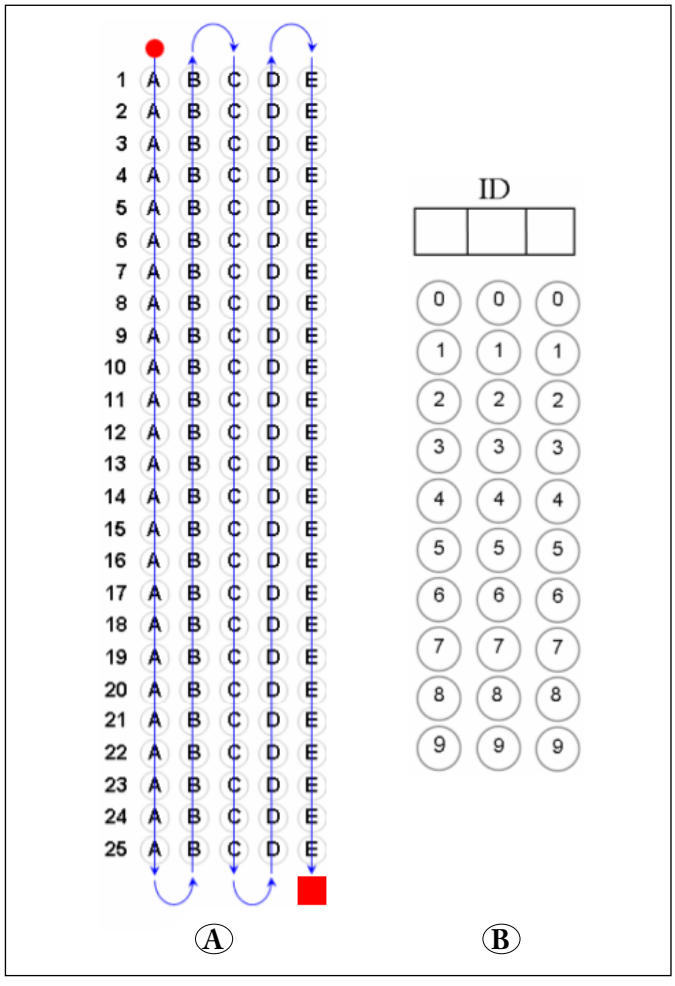


**Figure 2. A)** The illustration of the guidance system for the circle detection procedure in case the answer sheet has 25 questions. The starting and finishing points of the detection are indicated by red-filled dot and square objects, respectively. **B)** Student ID part of the answer sheet.

and has a distance δ to the origin. The equation for this representation is given in Equation (1).

$$x\cos(\theta)+y\sin(\theta)=\delta \quad (1)$$

When the angle θ is limited in a range of [0, 360], the normal parameters of a line are obtained as unique. Following this approach, normal parameters of each line set has a unique point in the slope-intercept plane as shown in Figure 1-b. As seen in this figure, there are number of sinusoids created using the normal representation given in Equation (1). They correspond to co-linear points intersected at a unique point of which coordinates are at (182, -1.54). This procedure is considered as detecting co-linear points and can be turned into the solution procedure for obtaining concurrent curves.

## 3. Results

The automatic scoring system presented in this study is tested on more than 1000 exam papers. Each exam question has 5 answer options (bubbles). The number of questions is 25 in each exam sheet. In order to follow the answer bubbles line by line, a guidance system is adapted to the circle detection algorithm as exhibited in Figure 2-a. According to the case shown in this figure, firstly, "A" bubbles of the first 25 questions are tracked and detected. Then the detection system is guided to detect "B" bubbles. This process continues until the "E" option of the question 25 is detected. Note that the starting and end positions for the detection are highlighted with the red-filled dot and red-filled square, respectively. It is expected that in addition to grading the answer sheet, the proposed system should be able to identify the student ID number (Figure 2-b).

In the experimental studies, more than 1000 answer sheets are graded using the system proposed. As a case, the grading

results of the answer sheets of 247 students are presented in Figure 3. The answer bubbles detected are indicated by blue colored circles. Centers of each bubble are also shown by red plus signs. In this case study, the students' ID numbers are also sought. Students mark their student id numbers specified by circles and the automatic grading system identifies the marked circles as well. The proposed system could successfully grade all the answer sheets and identify the students' ID numbers. It could achieve the objective with 100% accuracy. The computational platform where the grading operations performed uses Windows 8 (64 bit) operating system. It has a processor, Intel Core i3 with the speed of 2.4 GHz. The RAM capacity is 4 GB. Details of the computation that includes grading the answer sheets and identifying the student ID numbers are given in Table 1.

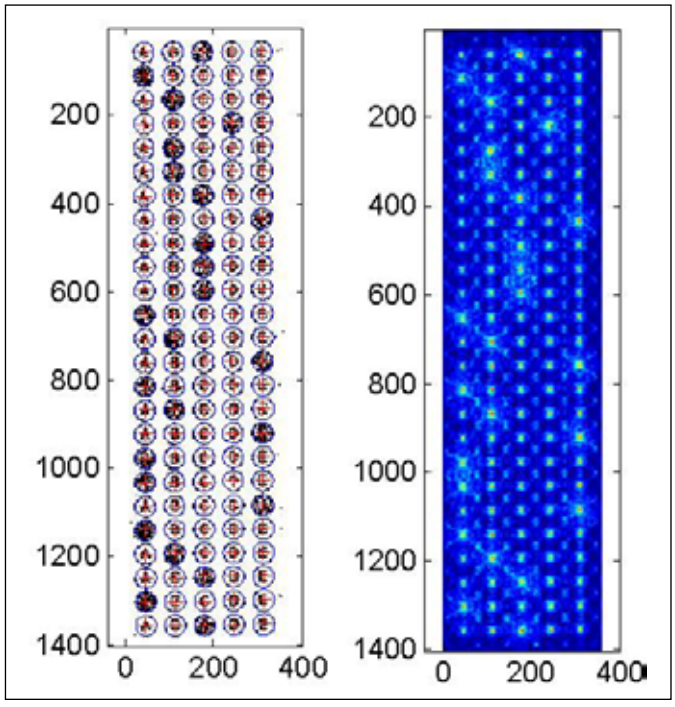


**Figure 3.** Results of the circle detection system for the answer sheet of the exam paper.

The system introduced in this study has capable of not only grading exam papers automatically but also providing opportunity for assessment of the graded exams. The assessment capability of the proposed system is presented in Figure 4. As shown in this figure, the answer sheets of 312 students are graded and an assessment graph is created. There are 25 questions in the exam paper and each question has five answer options. The options are specified by the letters A, B, C, D and E. The assessment algorithm created uses the marked options for each question. The correct answers are also indicated by the yellow colored boxes in Figure 4. Every box includes the numerical information showing the percentage of marked choices. This assessment graph enables that the lecturer or examiner can be able to

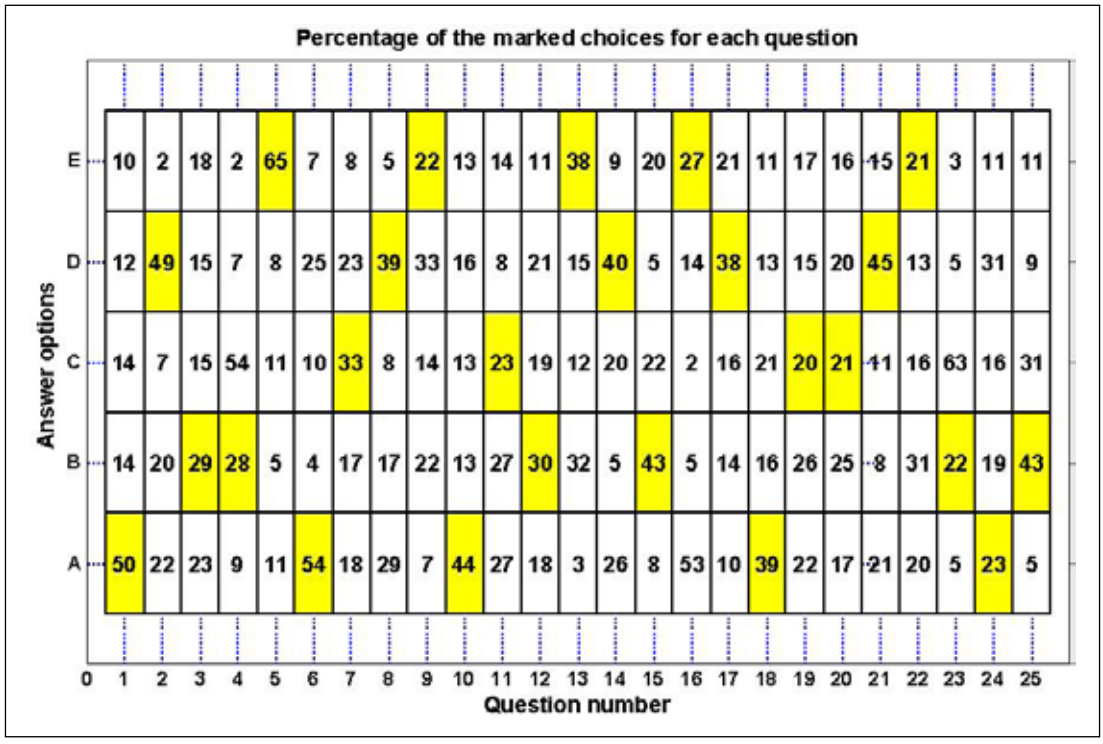


**Figure 4.** The assessment graph of 312 students' answers sheets. Each exam paper includes 25 questions and each question has 5 answer options indicated by A, B, C, D and E. Note that the numbers shown inside the boxes are rounded for simplicity.

**Table 1.** Grading results of 247 students' answer sheets. Each exam sheet has 25 questions. The student ID numbers specified by bubbles are also sought.

| Minimum Grading Time (sec) | Maximum Grading Time (sec) | Average Time (sec) | Standard Deviation (sec) | Total Time (min) |
|---|---|---|---|---|
| 4.615 | 29.269 | 12.084 | 5.170 | 49.345 |

evaluate the learning success of the all students. Note that the grading operation for this case study is conducted with total processing time; 55.034 min. Standard deviation is found as 4.348 sec. Average time which is required to complete one of the students' papers is 10.583 sec.

## 4. Conclusions

Automatic grading systems for the exam papers including multiple choice questions are widely used in the learning environments. Such systems are essential for achieving accurate and fast grading. In the market, some automatic grading systems are available. They need special forms and answer sheet formats. Also the bubbles and answer options have to follow some guidelines. Furthermore, such systems are closed to make implementation of the new approaches and methodologies. When the studies about automatic grading systems existing in the literature are investigated, it is seen that there is lack of a comprehensive solution. The automatic scoring system proposed in this paper provides a new perspective to achieve grading of the exam answer sheets. The system developed involves not only a new technique for grading multiple choice exams but also some highlights for the researchers who have plans to focus on this subject.

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