

A new application for reading optical form with standard scanner by using image processing techniques

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ABSTRACT

Multiple choice exams appear as the most common method used to measure student success in education systems in Turkey and around the world. Evaluation of multiple choice exams is usually done by optical form reading systems using expensive optical forms and optical scanners. The most important reason for using optical form reading systems is to reduce the error rate to zero in the evaluation process. In this study, an alternative system is proposed for the evaluation of multiple choice exams. The designed system is a web-based software with high accuracy on evaluating that contains optical form design module, session planning module and evaluation module. The form in which the designed template will be printed on A4 paper instead of a special optical form and the system in which standard scanners will be used instead of the optical scanner, uses the image processing algorithms in the OpenCV library in the evaluation process which is an intermediate library developed in C#. The proposed system is coded to run in parallel to speed up the evaluation process. In order to determine the performance of the proposed system, the optical forms filled by 208 students studying at Karamanoğlu Mehmetbey University, Department of Computer Engineering were evaluated. The accuracy rate of the system has been determined as 99.97%. It has been determined that 1 optical evaluation time, calculated by dividing the total time obtained by running in parallel, by the number of evaluated optical forms, varies between 1.7 seconds and 15 seconds, depending on the scanning resolution.

ARTICLE INFO

Research article

Received: 9.12.2022

Accepted: 14.02.2023

Keywords:

image preprocessing techniques, multiple choice exam, optical form reading, segmentation, thresholding

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1. Introduction

The education system is considered as a purposeful process. The process of observing a quality and showing the observation data with numbers is defined as measurement, and the process of extracting a meaning from the measured values is defined as evaluation. One of the most important processes of the education system is the measurement and evaluation phase, which includes measuring how well the information given is understood, that is, determining the extent to which the objectives have been achieved. Evaluation reveals the performance of the entire education system, including the educator. Accurate calculation of the performance of the education system is very important in terms of determining the operational and non-operational aspects of the system and perfecting the education system[1].

Multiple choice tests are used both on a large scale and on a local scale in our country. In our education system, large-scale

tests were started to be applied by ÖSYM, which was established in 1974, to centralize the exams made by faculties as a result of the increase in applications to universities [2]. With the widespread use of central multiple-choice exams, multiple-choice exams have started to be held at the local scale so that students who are in the preparation stage for these exams can adapt to the exam system. The most important reason why multiple-choice exams have become so widespread is that since it is easy to answer questions in these exams, they allow more comprehensive measurement due to the fact that more questions are asked. In addition, features such as obtaining statistics on the basis of questions in multiple-choice exams provide detailed information to the educator. Since participants are charged for centrally held multiple-choice exams, it facilitates the use of optical reading systems necessary for the reading and evaluation of these exams. Educators who want to prepare their students for national multiple-choice exams generally do not have the

opportunity to demand money for the exam they have prepared themselves. Therefore, educators usually evaluate multiple-choice exams manually. Manual multiple-choice exam evaluation is prone to errors; moreover, it takes a long time to transfer the data obtained to the computer environment to get detailed statistics, which is one of the most important features of multiple-choice exams.

The aim of this study is to develop a web-based optical form evaluation system for optical forms scanned with devices such as scanners or mobile phones, which are often in the hands of the institution or educator today, instead of purchasing an optical reader required for the evaluation of multiple-choice exams and using equipment that is costly in technical maintenance. The main purpose is to reduce the cost required for the evaluation of multiple choice exams. Since the system proposed in this study includes the answer sheet design, it will allow the use of standard A4 paper. In addition, since the proposed system has a module such as creating a session plan, it will also minimize cheating, which is the biggest problem of multiple choice exams.

Information about previous studies on optical form reading is given detailed.

Nguyen et al., in their published article, worked on the evaluation with high reliability and efficiency of answer sheets scanned with a digital camera by using image processing algorithms. Nguyen et al. tested the system they designed with 10000 questions and achieved an accuracy rate of 99.74% [3]. Aydemir worked on optical form reading in his master's thesis. Aydemir tested the system he designed with 28360 questions answered by 742 students in the foreign language exam and determined the accuracy rate of the developed system as 99.94% [4]. Al-Marakeby tried to find the evaluation results by processing the exam result images scanned using a digital camera with parallel processes thanks to the multi-core processor in his published article. Finally, classifier algorithms were preferred to determine whether the box was checked or not. As a result of the tests carried out with 200 multiple choice optical forms and 24000 question answers using different light, form angle originating from scanning, the success of the system was revealed as 99.8% [5]. Fisteus et al. have worked on a low-cost and portable computer vision-based system called "Eyegrade" for multiple choice exams in their article. In order to measure the performance of the system called "Eyegrade", the results of 233 students were evaluated and they measured that system made wrong assessment on 9 students paper and revealed the success rate as 96.1% [6]. In his article Sattayakawee studied a system for the evaluation of multiple choice exams with grid type answer sheets used in Thailand. In the tests made with 300 exam papers and 16500 questions, the accuracy rate of the proposed system was measured as 99.91% [7]. In their article, Şenol and Fidan designed an exam system that evaluates the optical forms scanned with a web camera developed in C#

language in order to read the optical forms used in multiple choice test systems and to provide more detailed and valuable information to the educators by making statistical analyzes. In order to measure the performance of the designed system, the answer sheets of 221 students were scanned with a web camera and errors were detected in 7 answer sheets and the performance of the system was calculated as 96.83% [8]. Patel et al., in their article published in 2015, worked on a mobile application based system they named "CheckIt". Patel et al. tried the "CheckIt" system with 310 quizzes and tests questions and achieved a success rate of 97.48% [9]. In the article they published, Hasan and Kareem worked on a system to be used in the evaluation of multiple choice exams. Hasan and Kareem determined the accuracy rate of the artificial neural network algorithms based system as 99.96% in the test they performed with 800 answer sheets and 58000 questions [10]. Yüksel et al. have worked on a mobile application-based optical form evaluation system in the article they published. The highest success of the system was measured as 99.7% in the tests made with 1000 questions on 20 answer sheets [11]. Gyamfi and Missah worked on the optical form evaluation system they proposed for multiple choice exams in their published articles. As a result of the tests, it was revealed that the system using unsupervised learning on the basis of pixels has better performance [12]. Loke et al. proposed a new method for optical form recognition in their published paper. In the first category, 6000 questions were filled and tested by people who were not trained on how to mark, and the accuracy rate of the proposed method was measured as 99.97%. In tests with printing and scanning errors, the accuracy rate of the proposed method was measured as 99.3% [13]. Küçükkara and Tümer worked on the reading and evaluation of answer sheets for multiple choice exams in their published articles. They tested the proposed system with 105750 answer sheets in three exams attended by 35250 students in Konya and calculated the accuracy rate as 99.76% [14]. Espitia et al., in the article they published, worked on the evaluation of the answer sheets of exams such as the university entrance exam or graduation exam in Colombia using image processing algorithms. The system designed by Espitia et al. was tested with 64940 answer sheets and it was found that it achieved an accuracy rate of 99.70% [15]. In the article they published, Afifi and Hussain studied classification-based algorithms for multiple choice exams. In their tests using MATLAB, they used different classification algorithms and were able to achieve the maximum accuracy rate of 99.78% by using the CNN classification algorithm [16]. Ha and Thu studied on optical form reading using MATLAB in the article they published. They measured the success rate of the developed system as 100% in their tests using 170 optical forms [17].

In this study, a system called "Multiple Choice Examination System" is proposed instead of costly optical form reading systems, in which the optical form designed by using the system can be printed on A4 paper and standard scanners are used instead of optical scanners. The designed system is

separated from previous studies by consisting of modules such as creating a seating plan, designing optical form and evaluating optical form.

In this article, the image processing steps used during optical form evaluation are explained in the second part. The application and evaluation steps are explained in detail in the third section, and the performance of the system is explained in the fourth section.

2. Material and Method

The system proposed in this study consists of a three-stage structure. The first stage consists of making the definitions including the optical form design, the second stage is the session plan and the printing of the optical forms customized according to the student and the examination, the third stage consists of scanning the marked optical forms and performing the evaluation process after uploading scanned optical forms to the system. Evaluation phase of optical forms consists of grayscale conversion, Gaussian smoothing filter, morphological opening process, thresholding and conversion to binary image, edge detection, contour extraction, and Hough circle transform, which are explained in detail below.

2.1. Convert to Grayscale

In colored images, each pixel is represented by 24-bit data. During image processing, instead of using the color values of 3 different colors in an image, a grayscale image consisting of values between 0 and 255, where a pixel can be expressed with 8-bit data without losing detail, is used. Thus, the size of the optical form image file is reduced to one third.

2.2. Gaussian Smoothing Filter

Using the Gauss function to blur the image, reduce detail and noise is called a Gaussian smoothing filter. Gaussian smoothing filter can be defined as two-dimensional convolution in general. The Gaussian smoothing filter can be expressed by the function shown in Equation (1) [18].

$$G(x) = \frac{1}{(2\pi\sigma^2)^{N/2}} e^{-(x-\mu)^2/(2\sigma^2)} \quad (1)$$

In Equation (1), “G” refers to Gaussian probability density function, “σ” refers to standard deviation of Gaussian noise, “e” refers to base of natural logarithm, “N” refers to the size of the image, “x” refers to grayscale value and “μ” refers to the mean value of Gaussian noise.

2.3. Morphological Opening

It is obtained by applying a dilation process after an erosion process. It is used to get rid of noise while preserving the properties of large shapes. Equation (2) shows the function of the morphological expansion operation.

$$A \circ B = (A \ominus B) \oplus B \quad (2)$$

In Equation (2); “A” refers to image to open and “B” refers to the structural element that determines the shape of the opening process.

2.4. Thresholding and Conversion to Binary

Thresholding, which is one of the most basic segmentation methods, is the process of separating the objects in the image from the background of the image. The image input, which is given as grayscale, is returned as a binary image. Basically, it is aimed to change the pixels below the determined threshold value in grayscale images to black pixels, i.e. 0, and to change the pixels to white, i.e. 255, higher than the threshold value. Thresholding is also used to remove noise in the image. Here, the success of the thresholding depends on the determined threshold value. Basically, the Otsu thresholding algorithm returns a single threshold value to minimize the within-class variance and maximize the variance between classes. Equation (3) shows the variance function between classes.

$$\sigma_w^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t) \quad (3)$$

In Equation (3); “σ_w” refers to within-class variance, “t” refers to threshold value, weights “ω₀” and “ω₁” refer to probabilities of two classes separated by “t” threshold, “σ₀” and “σ₁” refer to the variance of the two classes separated by the t threshold.

2.5. Canny Edge Detection

Canny edge detection method is one of the most common methods used to find the edges of objects and shapes in an image. In this method, two threshold values are given as parameters. The method generally consists of 5 steps. Table 1 shows pseudocodes of the Canny edge detection algorithm.

Table 1. Canny edge detection pseudocode

Start:

Apply noise reduction with Gaussian Blur
Refine edge with non-maximum suppression
Perform pixel continuity test using double threshold value and detect strong, weak and irrelevant pixels
Convert weak pixels to strong pixels by examining neighboring pixels by edge tracking with hysteresis.

End:

2.6. Contour Extraction

Contour extraction can be defined as finding a closed curve that seamlessly connects pixels of the same color and intensity by grouping them together. Commonly contours are objects found in an image.

2.7. Hough Circle Transform

The Hough transform was found by Paul Hough in 1962 to determine whether mathematically expressible shapes exist in the picture, and if so, its location and angle. The method works with simple bit voting logic. Dana H. Ballard made improvements in 1981 for the detection of objects more general to the algorithm[19]. During the Hough transform circle detection, the functions shown in Equations (4), (5) and (6) are used.

$$r^2 = (x - a)^2 + (y - b)^2 \quad (4)$$

$$a = x - r \times \cos(\theta) \quad (5)$$

$$b = y - r \times \sin(\theta) \quad (6)$$

In Equations (4), (5) and (6); “r” refers to radius of the circle, “a” refers to coordinate of the center of the circle on the x-axis “b” refers to Coordinate of the center of the circle on the y-axis, “ θ ” refers to angle between $(0, 2\pi)$, “x” refers to coordinate of the image point on the x-axis and “y” refers to coordinate of the image point on the y-axis.

2.8. Parallel Programming

Parallel programming, the foundation of which was laid by John Cocke and Daniel Slotnick in 1958 with a computer design called SOLOMON, refers to the completion of a large and time-consuming computation in a shorter time on multiple processors simultaneously [20]. It is predicted that the size of the optical form image files to be evaluated within the scope of this study will increase as the scanning resolutions increase and the evaluation process will take longer. Therefore, in this study, parallel programming structure is used to reduce the evaluation time.

3. Application

In order to create a multiple-choice exam system, first of all, pages were designed to carry out the definition processes to be made before the exam. In these pages; user operations, unit operations, exam definition procedures, exam correct answers procedures, student procedures to take the exam, classroom procedures, session planning processes and the design of the optical form to be used in the exam are carried out. The design of these pages is shown in Figure 1.

Figure 2 shows the evaluation workflow of the system. Image file containing optical form data respectively is subjected to image processing algorithms like grayscale conversion, application of Gaussian smoothing filter to reduce noise, applying morphological opening to remove black pixel distortions, thresholding and binary level transform, angular correction, contour extraction, QR code extraction and Hough

circle transform. To decide whether the option is checked, the largest square that will fit inside the circle is found, and the option is considered checked if at least 50% of the square's area is ticked.

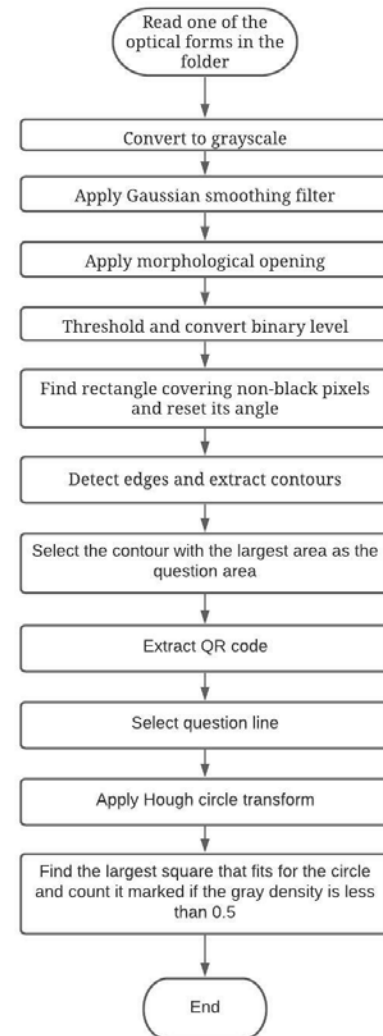
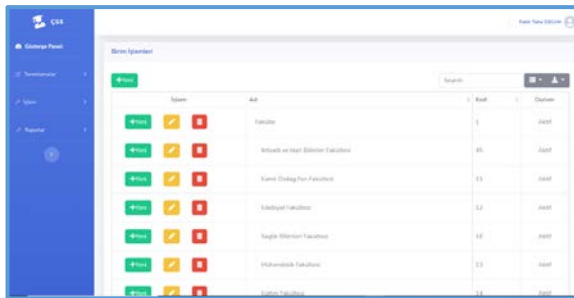
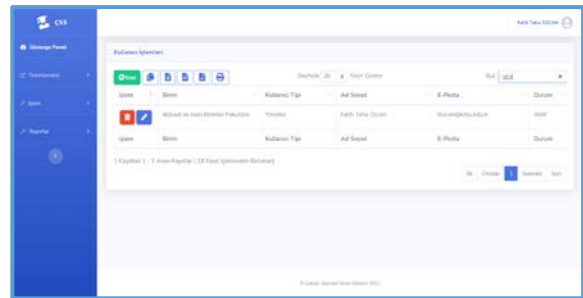


Figure 2. Evaluation workflow

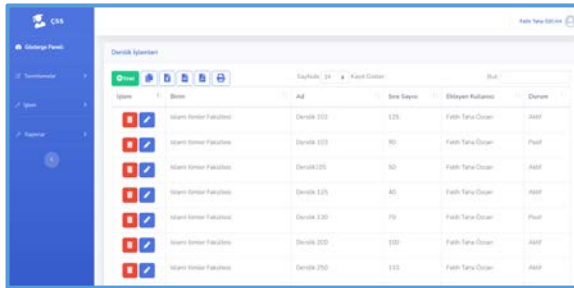
The results obtained when the techniques mentioned are applied to the optical form are shown in Figure 3. After the aforementioned pre-processing steps, QR code extraction was performed as seen in Figure 4. According to the location of the QR code found, it is decided whether the image is inverted and, if necessary, the image is rotated 180 degrees again.



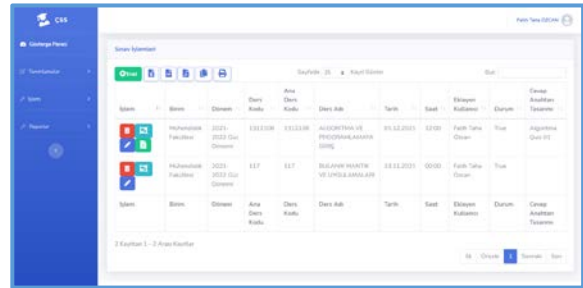
(a) Unit operations page



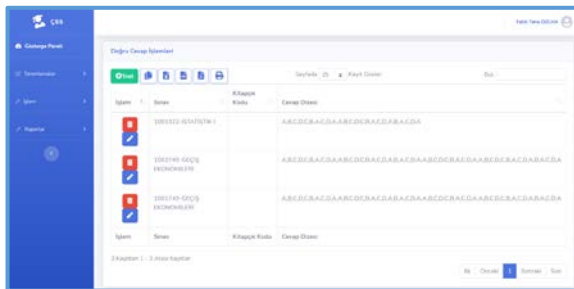
(b) User operations page



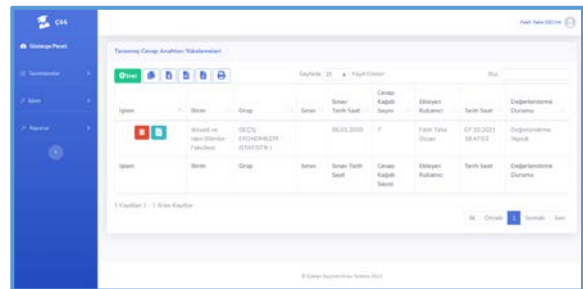
(c) Classroom operations page



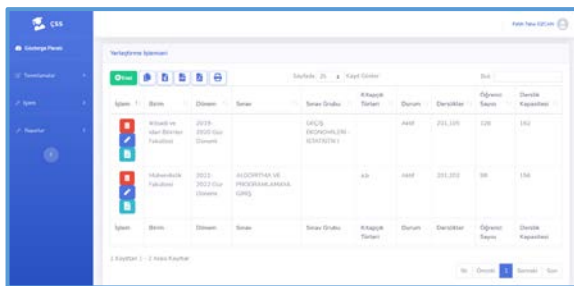
(d) Exam operations page



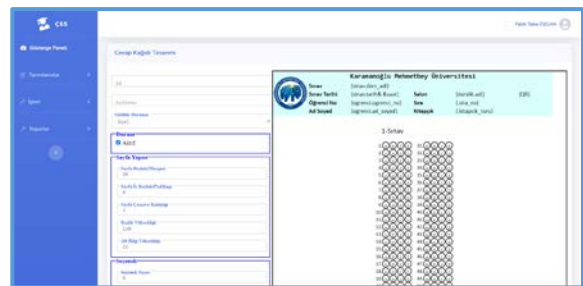
(e) Correct answer operations page



(f) Scanned optical form operations page



(g) Session planning operations page



(h) Optical form design page

Figure 1. Interface of the system

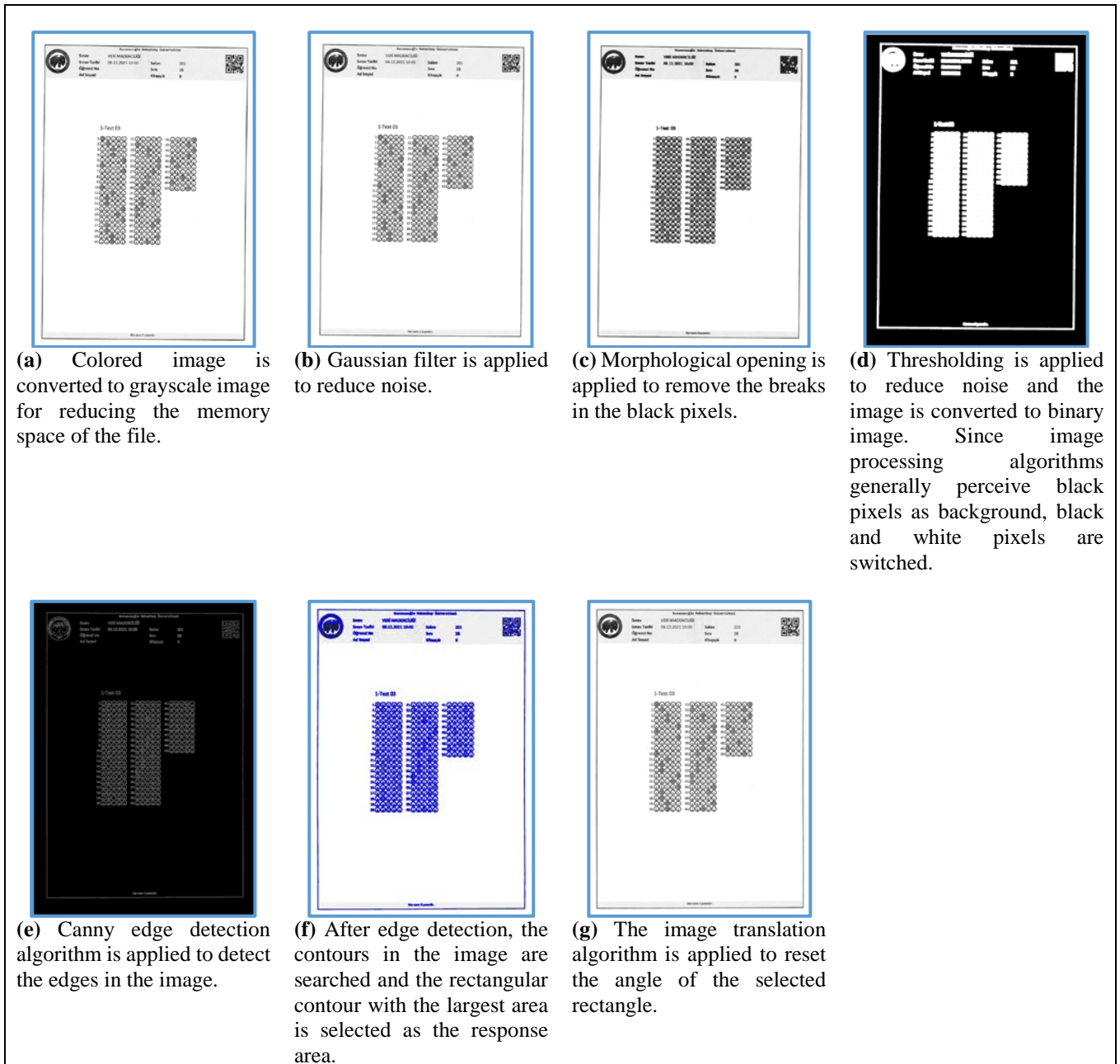


Figure 3. Evaluation detailed steps

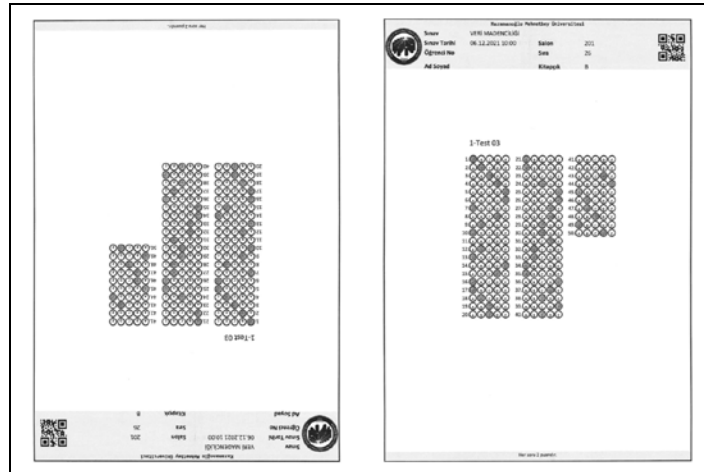


Figure 4. QR code check

Question evaluation steps were applied as shown in Figure 5.

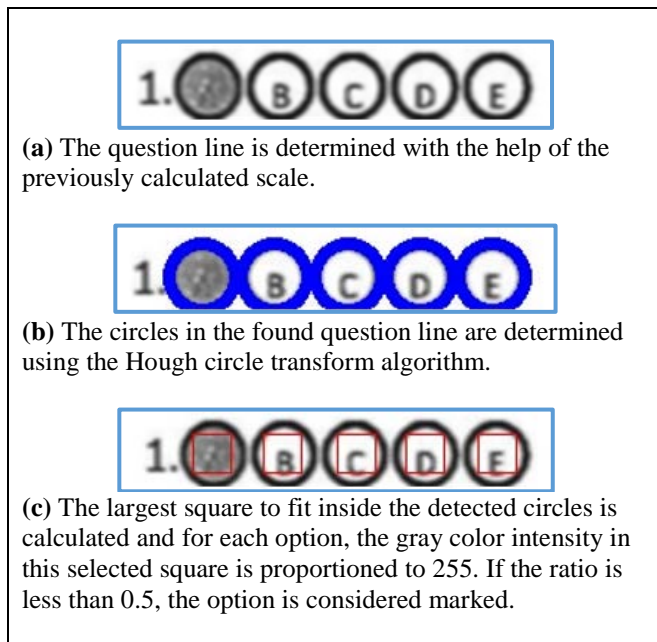


Figure 5. Question evaluation stages

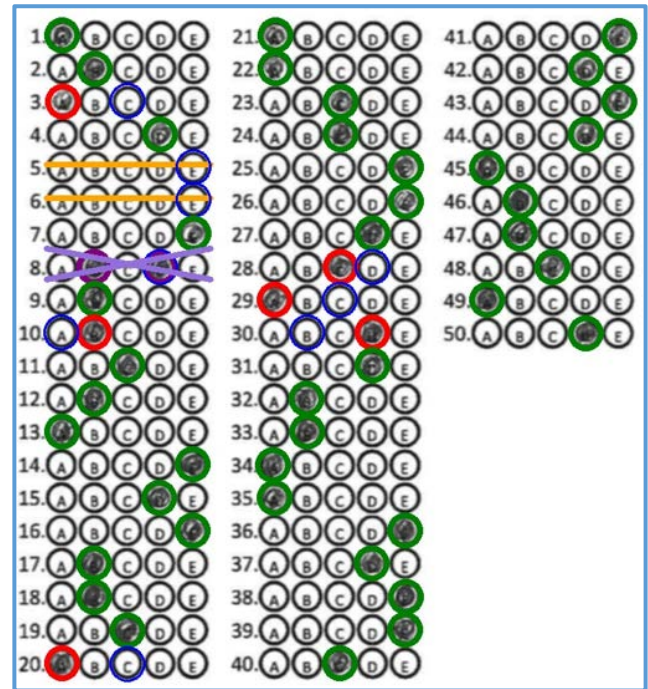


Figure 6. Answer sheet marked by the system

After evaluating all the questions, the correct answers are marked in green, the wrong answers in red, the correct answers in the wrong or empty options are marked in blue, and the invalid answers are marked in purple. An orange line is used for blank questions and a purple cross for invalid questions. The resulting markings are shown in Figure 6.

4. Result and Discussion

In order to measure the accuracy and performance of the designed system, the evaluation of 5785 questions in 208 optical forms in 3 different exams of the students studying at the Computer Engineering Department of Karamanoğlu Mehmetbey University was made at 3 different scanner resolution levels. As a result of these tests, the accuracy rate of the web-based optical form reading system was measured as 99.9%. In Figure 7, 3 different optical form designs used in exams are shown. The system designed in the study was tested

with questions with 4 or 5 options, different columns and questions.

In Table 2, the test results are shown in detail on the basis of scanning resolution. Since the evaluation period of the system is an important indicator in terms of performance, the tests were carried out both in parallel and in series. During the tests,

the time taken to evaluate one optical form is between 2.8 seconds and 1.8 seconds when scanned at 200 DPI resolution, between 8.3 seconds and 5.8 seconds when scanned at 300 DPI resolution, and between 16 seconds and 10.9 seconds when scanned at 600 DPI resolution. In Table 3, the time performance of the system is shown in detail on the basis of scanning resolution.

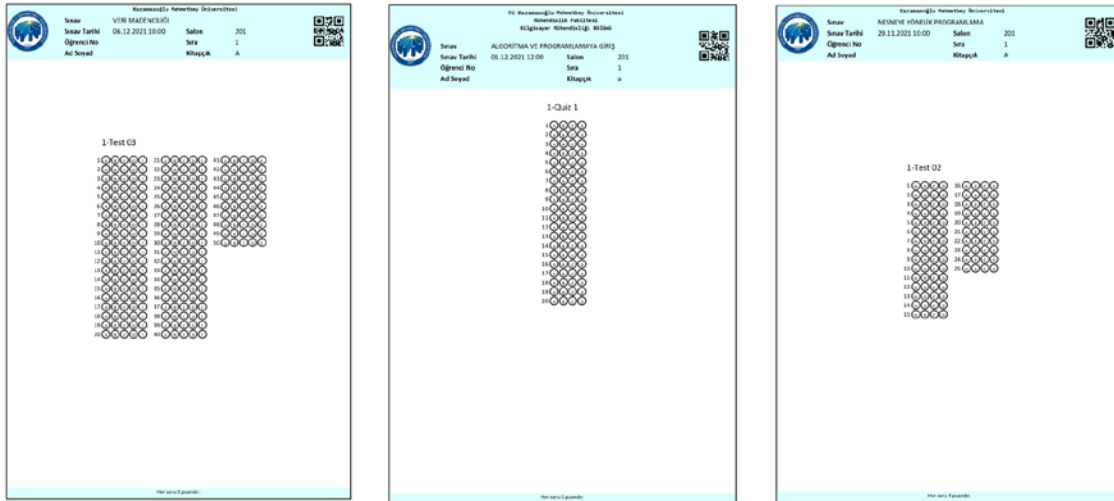


Figure 7. Optical form designs used in exams

Table 2. The accuracy performance of the system

DPI	Number of Optical Forms Uploaded		Percentage of Errorless Optical Forms	Number of Questions	Percentage of Questions Read Correctly	Number of Options	Percentage of Correctly Evaluated Options
	200	208	96.63%	5785	99.88%	25140	99.97%
300	208	93.75%	5785	99.74%	25140	99.94%	
600	208	87.98%	5785	99.46%	25140	99.88%	

Table 3. Time performance of the system

	Number of Optical Forms Evaluated	1 Optical Form Evaluation Time (Second)	1 Optical Form Evaluation Time (Seconds) in Parallel Mode
200 DPI	208	2.815	1.795
300 DPI	208	8.277	5.774
600 DPI	208	16.062	10.882

As a result of the test studies, it has been revealed that the most optimal performance of the system will be achieved with 200DPI scanning resolution and parallel operation. In order to increase the correct reading performance to 100%, it is

thought that it will be achieved by informing the students more about marking and the use of optical form.

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