Journal of Al-Qadisiyah for Computer Science and Mathematics Vol.17.(1) 2025,pp.Comp 202–213

University Of AL-Qadisiyah

Available online at www.qu.edu.iq/journalcm

JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS

ISSN:2521-3504(online) ISSN:2074-0204(print)

Evaluation System for Multiple-Choice Questions Using Optical Mark Recognition: A Survey

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ARTICLE INFO

Article history:
Received: 12 /11/2024
Rrevised form: 27 /11/2024
Accepted : 4 /3/2025
Available online: 30 /3/2025

Keywords:

OMR

Optical Mark Recognition

Assessments

MCQ

Answer sheet

ABSTRACT

performing bulk assessment corrections across various domains and applications can be an expensive and time-consuming task. Optical Mark Recognition (OMR) technology can be used to speed up this process. It is an automated data input method that captures the existence or absence of different marks (filled circles, crosses, and ticks) on printed papers, such as multiple-choice exams. OMR was originally introduced as a dedicated hardware solution and has since evolved into software solutions. However, many of these software solutions lack flexibility, particularly for the end users. This work reviews different papers related to the OMR topic and outlines their key features, datasets, processing time and accuracy. The goal of this review is to highlight areas in OMR that still require further research and development. In conclusion, areas where future research efforts should be directed are identified.

https://doi.org/10.29304/jqcsm.2025.17.11975

1. Introduction

Optical Mark Recognition (OMR) is a technique that enables a machine to recognize marks made on paper document, like ticks, bubbles, or checkmarks [1]. This technology is used in multiple-choice questions, which, according to [2], are the most widely used form of questions for different levels of assessments.

OMR technology originated from punched card technology. Early OMR techniques used light to detect the position of graphite pencils on the answer sheet, which was very large and unsuitable to use [3].

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In the 1970s an improvement in technology came, OMR machines were designed to direct light onto special sheets. Filled circles allowed only a small amount of light to pass through, creating a difference in light intensity compared to the empty or unfilled circles. Sensors would detect this difference to identify the filled circles. Major disadvantage was that if a person wants to change the OMR sheet's layout/template he needs to replace the hardware as well [4].

There are also a few drawbacks that narrow the scope of OMR technology:

- The paper quality and weight should range from 90-110 GSM (grams per square meter) for compatibility with the OMR sheet, making it more expensive than standard printed paper (A4 sheets).
- The OMR sheet must be very accurate and follow a specific format, any variation in the format may prevent processing by the same OMR machine.
- The OMR machine is a dedicated device that consists of an OMR scanner, OMR software and dedicated OMR sheets, which are highly expensive.
- Finally, the machine can only be used to evaluate the OMR sheets [7].

By 1999 technology has evolved, OMR software solutions based on image processing, which used microcomputers and scanners, were introduced [5]. This was a cost-effective solution for educational institutions such as, schools and universities that could not afford buying the machines. OMR evaluation methods are preferred over the manual methods when a vast volume of data needs to be collected and processed in a short time period, questionnaires consisting of multiple-choice questions or categories selections, high accuracy is required and when there are limited survey collectors [6].

Optical Mark Recognition (OMR) is used in different fields, including education for grading exams, elections for processing ballots, marketing surveys for data collection, healthcare for patient forms, and financial institutions for customer forms [5]

This paper provides a comprehensive review of the advancements in OMR technology, identifying challenges and offering suggestions for future studies.

Following this Introduction, a motivation in "Research motivation and objectives", and a review of OMR technology in "Literature Review" are presented. Followed by table summarizing the discussed studies. "Processing Time" shows the processing time in an ascending order. The section ends with "Advances of Technology**"** of the methods.

2. Research motivation and objectives

Multiple-choice questions are popular and most commonly used type of assessments used in exams to determine student's academic excellence and avoid any misinterpretation. However, in large institutions like schools and universities with limited budget, manual evaluation methods for these assessments can be impractical and require the allocation of teachers or instructors. OMR systems which are based on image-processing techniques can reduce time and cost for the evaluation process. However, current OMR solutions still face some limitations such as, flexibility of the OMR layout sheet, slow processing time, inaccuracy in recognizing marked answers. The aim of this research is to explore these limitations, find ways to improve them, suggest more efficient solutions.

3. Literature review

Many research studies have explored evaluation systems for multiple-choice questions (MCQ) using optical mark recognition (OMR) technology to enhance efficiency, accuracy, and cost-effectiveness. These studies can be categorized into two main approaches:

3.1 Traditional Approaches**:** Studies employing classical image processing techniques such as template matching, Hough Transform, and OCR-based detection.

Karunanayake [7] proposed an OMR sheet evaluation system in real time, using a low-cost web camera and a template matching based on image processing. It supports any format of OMR sheets. The template and primary images are captured, processed before applying template matching and extracting the region of interest. Finally, the compression of the two images is done to count the number of correct answers. The system was tested with 3 different formats of papers, each format containing 40, 20, and 50 answers respectively. Resulting in an accuracy of 97.6%. However, since the system relies on the web camera, the actual error came from an abnormal input image during the capturing process rather than from the algorithm itself.

Sanguansat [3] introduced a low-cost system for OMR applications. Users can design formats using Excel software. QR codes are used to align the scanned answer sheets. The system was tested with 35 students and an accuracy of 93.36% was obtained. However, it requires that the questionnaires remain in good condition to ensure accurate results.

Abdul Nabi & Aljarrah [8] suggested an automated multiple-choice system. It uses Optical Character Recognition (OCR) to recognize handwritten characters and numbers from the scanned images. The system was tested on 27 exam papers and achieved an accuracy of 94.63% for characters and 97.31% for numbers, but it was limited by its database size.

Bayar [9] makes use of the Hough transform method to detect the circles that represents answers on exam sheets. This study demonstrates the effectiveness of the Hough Transform in a structured environment, where accurate circle detection is essential for automated grading without requiring pre-determined templates. The system was tested on more than 1000 exam papers, each containing 25 questions with 5 answer options, and identified the student's ID numbers with 100% accuracy but the system might be affected by the different formats of sheets

In a more flexible application, **Hafeez et al** [4] introduced a system based on the Hough transform algorithm to improve the accuracy of bias correction in OMR documents, eliminating the need for fixed fiducial marks. The scanned image is processed to detect and correct any skew in the paper, then analyzed to determine the actual response of the user. Finally, a comparison between the template and the student's answer is made to calculate the score. Experiments were conducted on 86,913 answer sheets filled by students. The results showed that Hough transform decreased the error rate by 0.44% compared with traditional systems and 7.22% when using the Hough transform only. The system was sensitive to alignment and requires pre-determined circle positions.

Applying the Hough Transform in a less controlled environment, **Hafeez et al** [25] developed an OMR system that relies on smartphone cameras instead of traditional scanners, they applied the Hough Transform for better fault tolerance. The system was tested on 300 sheets in different lighting conditions, obtaining an accuracy of 97% but it suffers from certain constraints like sensitivity to angle and lighting variations, the system aimed to make OMR grading for everyday use without needing specialized scanning

Catalan [10] proposed a framework for automatically scoring multiple-choice questions (MCQ) exams using image processing techniques and readily available software, which is also includes a mechanism to provide feedback to students. Testing it on a total of 800 answer sheets for exams in 8 courses, the scoring accuracy is high with only 10 recorded errors out of 800 sheets. However, scanning of the answer sheets took 5-7 seconds per sheet. This is very slow compared to the speed of hardware-based OMR systems.

Alomran and Chai [11] presented an automated scoring system for multiple-choice questions (MCQ) based on image processing using MATLAB. Key features include segmented handwritten character recognition for student IDs, a user-friendly answer sheet that permits multiple answer attempts, and provides quick feedback that sends the results to students. The system was tested on 88 answer sheets and achieved 100% success rate for mark recognition, 95% for student ID recognition, but it suffers from several constraints.

Tümer et al [12] proposed economical Optical Mark Recognition (OMR) system developed for multiple-choice tests using Python, OpenCV, and the image processing operations like, conversion to grayscale, filtering with median blur, binarization with Otsu thresholding, edge detection. A total of 105,750 sheets were scanned and an accuracy of 99.76% was achieved.

Kumar et al [13] suggested an image processing approach that uses predefined grid-based system to evaluate the scanned OMR sheet. The system converts the image to grayscale, processes it through Hough circle transformation, followed by parallel line interpolation to ensure no circles are left undetected. The algorithm was tested on 10 different scanned images of OMR sheets, achieving high accuracy of 99.23%. However, the system requires to have a rough estimate of the radius of the circles in pixels. And only considers circular-shaped options.

Akhter et al [14] introduced a cost-effective recognition system based on digital image processing MATLAB. The system uploads scanned copies of both standard and student answer scripts. Process them, and a comparison between the two scripts is performed to determine the marks obtained by the student and points are deducted for wrong answers based on the teacher's instructions. it was tested with more than 1000 scanned answer scripts, high accuracy rate of 100% was achieved. However, the processing time is not as fast as that of traditional OMR when large student answer scripts are loaded at the same time.

Raundale et al [16] proposed a webcam-based Optical Mark Recognition (OMR) system. It captures an image using a laptop's webcam and extracts the relevant area, converts it to grayscale, and apply edge detection and contour extraction techniques. The bubbles that represent answers are identified using Hough Circle Transform. And the results are stored in an Excel sheet for documentation. This solution is highly dependent on webcam quality, so the accuracy might be reduced.

Ware et al [17] developed a cost-effective solution to the optical mark recognition (OMR) software. The system was implemented using Python and OpenCV for performing image processing techniques, and a comparison of the student's answers with an answer key file for grading. The system was tested using a manually generated sample dataset, and provided the results in an online format accessible to both students and admins. The main limitation is that the questionnaire format used remains static.

Calado et al [18] proposed a web-based software (SICOA) used to create multiple-choice exams, correct, and evaluate them, and generate reports. It is implemented using many techniques including OMR, OpenCV, QR codes, and other technologies. Printed marks are captured and processed. The system was tested in several phases. A total of 37,775 exams were evaluated in two phases: 31,749 exams in the first phase, with 17 hours of correction time and 48 grade changes due to complaints, and 6,026 exams in the second phase, evaluated in 5 hours with no complaints. Grade alterations were caused by two factors: on one hand, candidates sometimes did not fill in the exam marks as instructed, and on the other hand, the scanning accuracy was not as good as desired.

Silao & Luciano [19] developed an Automated Test Item Analysis System with OMR for the evaluation and analysis of test items at high schools. It was developed using Agile software development. System design was based on the approved guidelines, software, and hardware specifications as agreed between the researchers and stakeholders. The (GUI) was created in a web-based environment using Bootstrap, HTML5 and others. It was designed to be responsive for different devices and platforms. It was evaluated by IT experts and end-users based on ISO/IEC 25010 standards, showing high quality, reduced human mistakes, and faster result analysis, with successful user acceptance testing in high school environments.

Ascencio et al [20] proposed a system that uses computer vision techniques to evaluate answers on multiple-choice test. It was implemented in Python with OpenCV library for the task of image processing, like contour detection and optical mark recognition (OMR). The system analyzes uploaded photos of test sheets, detects marked answers, compare them to a reference template and computes the score, although the system worked in an efficient manner, it suffered from certain limitations, such as only one format of the paper is allowed and if several options were checked, it will be regarded as incorrect.

In place of pricey conventional OMR devices, **Kommey et al** [21] presented a software that is more affordable and uses the camera on smartphones to process images. the system employs Telegram API as a free cloud for storage with 90% accuracy in identifying answers. However, illumination and camera quality have a major impact on the system's performance. Moreover, it requires a robust internet connection.

Salih [22] suggested a G-MCO system using computer vision techniques. The answer sheet is captured using a digital camera, and converted to binary format for processing. Then it passes through stages to detect key bookmarks for questions and options. The algorithm was tested with input images in PNG and JPG format, resulting in an accuracy of about 99%. Additionally, the algorithm was not affected by the image quality.

Subrahmanyam et al [27] presented a cost-effective Optical Mark Recognition (OMR) system that allows answer sheets to be directly analyzed through a mobile device's camera using image processing techniques. The system was tested with the participation of 100 students and achieved an accuracy of 99.76%. It can be used for educational assessments and similar evaluations. But it experiences a decrease when used on damaged forms. Moreover, the slow processing time makes it unsuitable for large scale-evaluations.

Özcan & Eldem [23] suggested a web-based system to evaluate multiple-choice questions. The system includes modules for designing optical forms, planning sessions, and evaluating scanned optical forms. The evaluation process uses the image processing techniques such as grayscale conversion and Hough circle transform. The optical forms filled by 208 students were evaluated, and the accuracy rate of the system was determined to be 99.97%. The limitations include reliance on scan resolution, sensitivity to lighting and image quality, and the added complexity of using parallel programming.

Hadžić et al [24] presented a software system for the automatic reading, storing, and evaluation of scanned evaluation sheets that was developed. The software system was developed using .NET technology in the C# programming language as a desktop application. It offers two methods: a semi-automatic method, where reading the sheets is done one at a time, and an automatic method in which a large number of sheets are placed in one folder. First, the system corrects any tilt by checking the positions of the markers. Then, it reads the student's answers based on the selected marks. About 4,000 assessment sheets were examined and evaluated. The system generally produced satisfactory results, though one student reported an issue regarding the interpretation on the evaluation sheet.

The following diagram illustrates the workflow of traditional OMR approaches

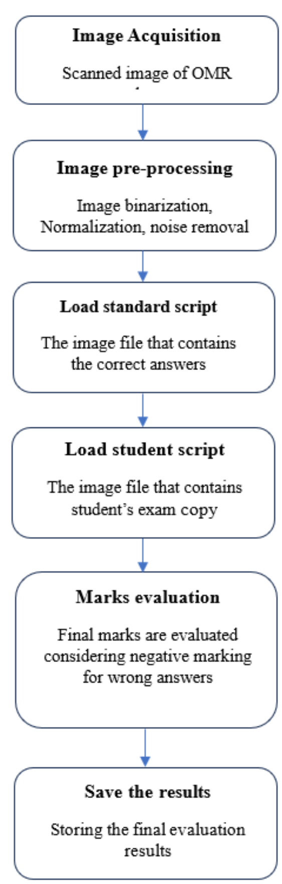

Fig. 1 - System workflow of Traditional Approaches

***3.2 Modern Approaches*:** Studies utilizing deep learning models, such as Convolutional Neural Networks (CNN) and object detection techniques like YOLO.

Afifi and Hussain [15] developed a system for multiple-choice assessments by using machine learning to minimize the restrictions in the existing OMR systems. The system uses models like Convolutional Neural Networks (CNN) to classify each answer box. A dataset was gathered using six real MCQ-based assessments with 10,980 verified answers, 202 crossed out answers, and 22,367 blank answer boxes. The results have shown that the CNN model achieved the best accuracy of 92.66%, while the use of a two-stage approach significantly improved the classification. One of the main drawbacks was the heavy dependence on the size of the training data, in addition to the slow processing time of complicated models, like CNN.

Mahmud et al [26] proposed an innovative approach to simplifies the evaluation of multiple-choice questions (MCQ) by combining Optical Character Recognition (OCR) with object detection techniques. YOLOv8 is employed to detect the marks on the answer sheet, such as filled circles or crossed marks, while Tesseract OCR extracts the question numbers. The detected answers are then compared with the correct answers to determine scores based on correct, incorrect, and unanswered questions. The system was tested on 50 images. High accuracy was achieved (0.98 F1 score and 0.99 mAP), a key advantage is that it does not require a fixed template sheet, although it may face challenges with low quality images, misclassifying false positive as valid objects outside the MCQ region.

The following diagram illustrates the workflow of Modern Approaches

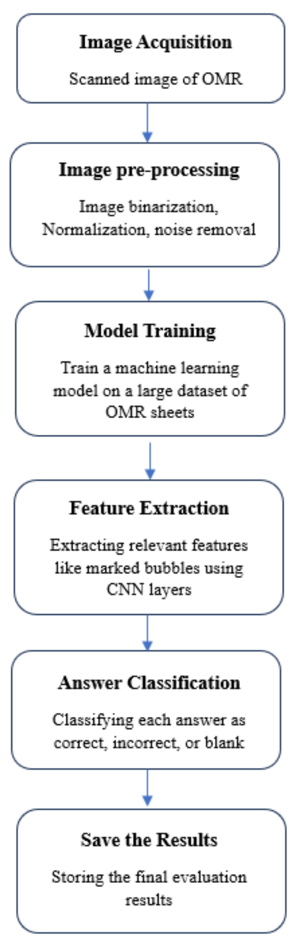

Fig. 2 - System workflow of Modern Approaches

Table 1. Summary of discussed researches

Reference	Year	Method	Dataset	Accuracy
[7]	2015	Image processing with template matching	3 formats containing 40, 20,50 answers	97.6%
[3]	2015	Image processing using pattern recognition and pixel counting	Tested with 35 students	93.36%
[8]	2016	Image processing with OCR	27 exam papers	94.63% for Ch, 97.31% for No
[9]	2016	Image processing using Hough Transform method	1000 exam papers, each containing 25 questions	100%
[10]	2017	Digital image processing with Octave scripts	800 answer sheets	98.75%
[11]	2018	Image processing with OCR	Tested on 88 answer sheets	100% for mark, 95% for student ID
[12]	2018	Image Processing techniques	105,750 forms	99.76%.
[13]	2018	Image processing using Hough Transform method	10 OMR sheets	99.23%
[14]	2019	Image Processing techniques	1000 scanned answer scripts	100%
[15]	2019	Machine learning (CNN)	10,980 confirmed answers, 202 crossed out answers, 22,367 blank answer boxes	92.66% with CNN
[16]	2019	Image processing with OpenCV	Webcam images of answer sheets	Fulfills basic needs for institutions
[17]	2019	Image processing techniques	Sample dataset	Support various marking schemes
[18]	2019	Web-based OMR software	37,775 exams in two phases	varies; 48 grades altered due to complaints
[19]	2021	Image processing techniques	High school bubble sheet	High quality
[20]	2021	Image processing using OpenCV	Fixed format answer sheet	Matches human

				grading accuracy
[21]	2022	Image processing with OpenCV	Smartphone images with specific format	90%
[22]	2022	Image processing with Computer Vision Techniques, Bookmark Detection	Digital camera images (PNG, JPG)	99%
[27]	2022	Image processing techniques	Multiple-choice answer sheets tested with 100 students	99.76%
[4]	2023	Image processing using Hough Transform	86,913 filled sheets	99.56%
[23]	2023	Image processing with OpenCV	208 optical forms filled by students	99.97%
[24]	2023	Image processing techniques	4,000 assessment sheets	Generally reliable
[25]	2024	Image processing using smartphone cameras	300 OMR sheet	97%
[26]	2024	OCR with YOLOv8 object detection	50 MCQ script images	0.98 F1 score, 0.99 mAP

Table 2. The limitations of the discussed studies

Reference	Limitations
[7]	Relies on web camera quality
[3]	Requires good conditions for Questionnaires
[8]	Limited template database
[9]	Affected by sheet format variations
[10]	Slow processing time
[11]	Constraints with ID recognition
[12]	Errors caused by damaged QR codes, incomplete or unclear marks
[13]	Require radius estimation, considers only circular-shaped options
[14]	Slow processing time with large data
[15]	Requires large training data, slow with CNN
[16]	Depends on webcam and lighting

[17]	Static questionnaire format
[18]	Accuracy affected by mark filling, limited by scanner quality
[19]	Limited to high school use
[20]	Single format, multiple selections marked as incorrect
[21]	Depends on camera quality, lighting, requires internet
[22]	Requires well-shaded circle
[27]	Decreased accuracy when processing damaged answer sheets
[4]	Sensitive to alignment, requires pre-determined circle position
[23]	Sensitive to scan resolution, shading quality, and requires good lighting
[24]	Relies on accurate shading
[25]	Sensitive to lighting conditions and phone angle
[26]	Challenges with low-quality images (false positives outside MCQ region)

4. Processing Time

The time required to evaluate Optical Mark Recognition (OMR) solutions differs among studies, as illustrated in Table 2. Many factors, such as the techniques used, the image resolution (DPI), and the computational resources available can cause this variation. **Alomran et al** [11] suggested the faster solutions, achieving a low processing time of 0.4 seconds per sheet, making them suitable for large-scale applications, while others, such as **Subrahmanyam et al** [27] which processing time of less than 20 seconds, might focus on accuracy over speed. Improving processing time is essential, especially for large assessments, as it directly affects how efficient these systems are.

Table 3. Document average processing time for an OMR sheet

proposal	**Time in seconds**
Alomran et al [11]	0.4
Sanguansat [3]	0.74
Abdul Nabi et al [8]	1 - 4
Karunanayake [7]	2.00
Calado et al [18]	2-3
Tümer et al [12]	2.4
Eldem et al [23]	1.8 to 16 (depending on DPI: 200, 300 or 600)
Mahmud et al [26]	3.5
Catalan [10]	5-7

Bayar [9]	10.583
Subrahmanyam et al [27]	< 20

5. Advances of Technology

The recent evolution in machine learning, particularly in deep learning techniques like convolutional neural networks (CNNs), have opened new possibilities for Optical Mark Recognition (OMR) applications. **Afifi and Hussain** [15] used artificial Intelligence techniques, whereas **Mahmud et al** [26] applied deep learning methods by combining YOLOv8 object detection model Optical Character Recognition (OCR) to detect marks on answer sheets, such as filled circles or crossed marks, additionally Tesseract OCR was employed to extract question numbers, demonstrating the effectiveness of combining object detection and text recognition in OMR systems.

6. Discussion

The examined studies demonstrate beneficial and problematic aspects of both two OMR system implementation approaches. The combination of Hough Transform and template matching works well for structured environments but their performance depends on templates along with image file quality. The YOLO model along with CNN demonstrate superior flexibility alongside enhanced accuracy when dealing with complex and non-structured environments. Despite their effectiveness these systems require extensive training data and access to powerful computing capabilities.

These hybrid models which integrate machine learning algorithms for classification with traditional methods in preprocessing development demonstrate the best performance regarding accuracy and efficiency. The combination of YOLOv8 and OCR technology used by Mahmud et al. (26] leads to improved accuracy levels without the need for template constraints.

7. Conclusion

The research investigated OMR approaches using conventional and machine-learning techniques. Traditional methods work efficiently during structured testing yet they face restrictions which stem from predefined templates. Applicating CNN-based approaches provides high precision performance in OMR systems but requires intensive computational resources to operate. The surveyed methods that integrate YOLO models together with OCR prove to be the leading approach for improving Optical Mark Recognition systems.

The following studies should focus on maximizing the efficiency of these combined systems by:

- Model developers should create lightweight CNN structures which enhance processing speed during inference time.
- YOLOv8 object detection models serve template-independent recognition through a template-free recognition approach.
- The training of models with multilingual datasets enables them to support different languages.
- Mobile-based OMR applications using cloud integration serve real-time assessments as the primary focus.

The methodology will create OMR systems that are efficient and scalable thus resolving the issues found in the analyzed surveys.

Acknowledgements

The authors are thankful to the department of computer science, Mustansiriyah University (www.uomustansiriyah.edu.iq) in Baghdad, Iraq, for supporting this paper.

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