Image Processing-Driven OMR Evaluation

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Abstract

Optical Mark Recognition (OMR) technology plays a pivotal role in automating the evaluation of standardized tests, surveys, and forms. This paper presents a novel approach to OMR system efficiency enhancement through a pixel-based unsupervised classification algorithm. By leveraging circular shapes for bubble representation and grayscale colors, the algorithm optimizes resource utilization and reduces printing costs while ensuring high accuracy. Rigorous evaluation across dummy MCQ-type examinations demonstrates an impressive accuracy rate of 96.9%, surpassing existing methods. These results underscore the potential for substantial advancements in OMR technology, paving the way for future research into diverse applications and alternative data structures.

Keywords: Optical Mark Recognition, Image Processing, Automated Grading, Bubble Detection, Accuracy Assessment

1. Introduction

Optical Mark Recognition (OMR) technology has emerged as a cornerstone in the automation of grading processes for standardized tests, surveys, and various forms. By leveraging advanced image processing techniques, OMR systems streamline the interpretation of marked answer sheets, significantly reducing manual effort and expediting result dissemination. Despite their effectiveness, existing OMR methodologies encounter challenges related to processing speed, accuracy, and cost-effectiveness. This paper presents a novel approach aimed at addressing these challenges by introducing a pixel-based unsupervised classification algorithm.

Grounded in the principles of image processing and signal analysis, particularly the utilization of Fast Fourier Transform (FFT) techniques, the proposed algorithm represents a paradigm shift in OMR system efficiency enhancement. Unlike traditional object-based classification methods, which may exhibit limitations such as reduced accuracy and slow processing speeds, the pixel-based approach offers a promising solution to optimize resource utilization and reduce printing costs while maintaining high accuracy.

The methodology involves several key steps: initial contour detection to identify shaded regions on the OMR sheet, followed by the identification of bubble shapes and the extraction of relevant features. The algorithm utilizes FFT techniques to analyze frequency components and identify marked answers. Through careful preprocessing techniques, including noise filtering and contrast enhancement, the algorithm ensures robust performance across varying conditions.

Rigorous evaluation of the proposed algorithm is conducted through dummy MCQ-type examinations, providing a comprehensive assessment of its efficiency and accuracy. Results from these evaluations demonstrate an impressive accuracy rate of 96.9%, surpassing existing object-based classification methods. These findings underscore the potential for substantial advancements in OMR technology, paving the way for future research into diverse applications and alternative data structures.

The proposed methodology holds promise for broader applications in areas such as surveys, evaluations, and data collection. By embracing innovation and leveraging advanced image processing techniques, this study heralds a new era in OMR technology, promising enhanced efficiency and accuracy in automated grading processes.

2. Literature Survey

The research paper explores Optical Mark Recognition (OMR) systems, emphasizing their role in processing MCQ answer sheets and the need for enhanced efficiency. Through a literature review, prevalent OMR methodologies are scrutinized, revealing limitations such as slow processing speeds and suboptimal accuracy. To address these, the paper introduces a pixel-based unsupervised classification algorithm, optimizing space utilization and reducing printing expenses. Rigorous evaluation via dummy MCQ-type examinations highlights substantial enhancements in speed and accuracy compared to previous methods. The findings underscore broader implications for OMR technology and suggest avenues for future research [1].

Kanjalkar et al. [2] present a timely and economical approach to OMR sheet evaluation, tackling the limitations of traditional methods reliant on expensive scanning equipment. By leveraging image processing techniques and a low-cost web camera, their proposed system offers a promising alternative for grading multiple-choice exams. The literature on OMR technology underscores its widespread application in various fields, including education and surveys, yet its dependence on specialized machinery and specific paper formats has posed challenges. This study's innovative methodology, utilizing template matching and binary image processing, demonstrates impressive accuracy rates across different MCQ paper formats. With an average accuracy of 97.6% and processing times under 2 seconds per sheet, the proposed system presents a compelling solution for efficient and accurate OMR evaluation without the need for costly equipment.

Ahad et al. [3] present a pertinent response to the pressing need for swift information extraction from Optical Mark Recognition (OMR) sheets, crucial in contexts such as educational assessments and surveys. The paper highlights the prevalent utilization of OMR technology across various sectors due to its simplicity and cost-effectiveness. Despite its advantages, traditional OMR systems encounter challenges such as dependence on specialized equipment, susceptibility to errors, and inefficiencies in handling damaged sheets. In this context, the proposed approach, employing image processing techniques and pattern recognition, offers a promising solution. By utilizing readily available scanning devices and implementing robust algorithms, the system demonstrates notable improvements in time and cost efficiency, particularly advantageous for scenarios requiring rapid data retrieval and processing from OMR sheets.

The proposed system by the authors [4] offers a promising solution to streamline the evaluation of Optical Mark Recognition (OMR) sheets, crucial for grading purposes in various educational and survey contexts. By employing image processing techniques such as median filtering, RGB to Gray conversion, edge detection, and complementing of images, the system efficiently identifies marked answers on OMR sheets, ultimately displaying the total marks. This approach eliminates the need for heavy machinery and expensive scanners, significantly reducing both time and cost. Furthermore, the system's block diagram illustrates a straightforward process involving a webcam, conveyor belt, and computer for computation purposes, making it accessible and adaptable. With an accuracy rate of 88% and a maximum processing time of 60 seconds, the proposed system demonstrates potential as a cost-effective and efficient tool for evaluating answer sheets across various examinations. Overall, this work presents a valuable contribution to the field of OMR technology, offering a practical solution with wide-ranging applications in education and beyond.

Himabindu et al.[5] introduce a novel approach to the evaluation of Optical Mark Recognition (OMR) sheets through computer vision techniques, addressing the limitations of traditional OMR systems. The paper begins by highlighting the widespread use of OMR technology in various domains, including examination evaluation, survey forms, and competitive examinations. However, the authors identify challenges such as high costs and limited accessibility to OMR devices, particularly in developing countries. Against this backdrop, they propose a new image-based low-cost OMR technique, leveraging computer vision methodologies. The methodology section delineates key techniques employed, including image scan, tilt correction, scanning error correction, regional deformation correction, and mark recognition. By utilizing a standard scanner and software, the proposed system offers an efficient alternative to conventional OMR devices. The paper further elaborates on various image processing techniques, such as median filtering, RGB to grayscale conversion, edge detection, complementing of images, thresholding, and the Canny algorithm, demonstrating their relevance to the OMR evaluation process. Results presented indicate the robustness and effectiveness of the proposed system in processing a large volume of questionnaires, with an emphasis on accuracy and processing speed. Ultimately, the paper underscores the potential of the proposed system to revolutionize OMR evaluation by providing a cost-effective and efficient solution with broad applications in education, surveys, and beyond.

Kumar et al. [6] present a cost-effective real-time image processing-based optical mark reader (OMR) system aimed at addressing the limitations of traditional OMR evaluation methods. They highlight the prevalence of multiple-choice question (MCQ) exams and the dependency on specialized machines and sheets for OMR evaluation, which poses economic challenges, particularly for smaller institutions. Their proposed system leverages image processing algorithms to detect and evaluate responses on scanned OMR sheets without the need for special hardware or dedicated OMR sheets, thereby making the process more accessible and economical. The algorithm encompasses steps such as Hough Circle Transform for circle detection, parallel line interpolation for error correction, and binary thresholding for response detection, ultimately enabling real-time evaluation of OMR sheets. The study demonstrates the effectiveness of the proposed approach through experimental results on both straight and tilted OMR sheet images, highlighting its potential to revolutionize OMR evaluation by offering a more flexible and cost-efficient solution.

The study by Küçükkara and Tümer [7] provides a comprehensive review of image processing techniques applied to optical mark recognition (OMR) systems for multiple-choice tests. They address the limitations of traditional OMR systems, such as high costs and reliance on specialized equipment, by proposing a novel method that leverages Python programming language with OpenCV, Imutils, and ZBar libraries. Previous research in this field has explored various approaches, including mobile applications and Java-based systems, but lacked comprehensive evaluation of recognition accuracy and performance metrics. Küçükkara and Tümer's work fills this gap by demonstrating a recognition success rate of 99.76% through extensive testing involving over 100,000 optical forms. Their system streamlines the OMR process by converting scanned images, detecting edges and contours, and evaluating marked bubbles. The study highlights practical advantages such as compatibility with standard scanners and black-and-white printouts, making it a cost-effective and efficient solution for educational institutions and assessment centers.

The paper by Akhter et al. [8] addresses the challenge of evaluating Optical Mark Recognition (OMR) sheets, particularly in the context of developing countries like Bangladesh where paper forms remain prevalent. They propose a cost-effective automated system based on digital image processing to instantly evaluate student answer scripts for multiple-choice questions. Their system aims to not only detect marked answers but also implement features such as negative marking and grace points for incorrect or missing answers. By developing and implementing the system in MATLAB, the authors demonstrate its effectiveness through extensive testing on a large number of exam papers. They compare their approach with existing OMR systems, highlighting its advantages in terms of accessibility, affordability, and accuracy. The paper contributes to the field by offering a practical solution for automating the evaluation of OMR sheets, which could significantly streamline assessment processes in educational institutions and beyond.

The paper by Gupta and Avasthi [9] proposes an image-based low-cost alternative to traditional Optical Mark Recognition (OMR) processes for surveys and research. The literature review contextualizes the study within existing OMR technologies, highlighting their use in various applications such as institutional research, community surveys, and examinations. It identifies drawbacks of traditional OMR, including its requirement for high-quality paper and expensive scanning hardware, which limits its accessibility, especially for small-scale organizations. The review discusses related work, including systems utilizing image scanners and software development kits for OMR recognition. It also outlines techniques for template design, image capturing, and processing, emphasizing the importance of aligning scanned images with predefined templates to accurately identify marked responses. The proposed method leverages low-cost flatbed scanners and image processing techniques to achieve comparable efficiency to traditional OMR systems. The review concludes by identifying future directions, such as implementing optical character recognition (OCR) and barcode technologies to enhance form processing and authentication. Overall, the literature review provides a comprehensive overview of existing OMR technologies and sets the stage for the proposed image-based approach.

The literature review for the paper titled "Image Processing for Enhanced OMR Answer Matching Precision" [10] encompasses a comprehensive exploration of Optical Mark Recognition (OMR) techniques, particularly focusing on image processing methodologies to improve accuracy in answer matching. It delves into the historical evolution of OMR technology from its inception, highlighting key milestones such as the IBM 805 Test Scoring Machine in the 1950s. Subsequent advancements, including low-cost FPGA-based systems and template-free assessment approaches, are examined, demonstrating the ongoing pursuit of cost-effective and flexible OMR solutions. Various image processing techniques, such as template matching, contour detection, and convolutional neural networks, are discussed in the context of their applications in OMR systems. The review emphasizes the need for improved accuracy and flexibility, particularly in detecting regions of interest (ROI) and handling different OMR form designs. It sets the stage for the proposed research by identifying existing challenges and gaps in current OMR marking techniques, laying the groundwork for the development of an enhanced algorithm for OMR answer matching precision.

The paper by L. D. Largo et al.[11] presents a novel approach to automating the grading of bubble sheet multiple-choice exams using mobile phone-based image processing with Optical Mark Recognition (OMR) algorithms. The authors address the longstanding issue of manual grading's time-consuming nature by introducing a mobile application that utilizes image processing techniques powered by Python and OpenCV. They highlight the significance of OMR technology in reducing teachers' workload and providing prompt feedback to students. The literature review section discusses various studies employing image processing for OMR, including techniques such as pixel-based unsupervised classification, low-cost OMR systems, and image segmentation methods. The authors emphasize the importance of accuracy and efficiency in OMR systems and propose their solution, which achieves a commendable accuracy rate of 90.1% in grading bubble sheets. Overall, the paper contributes to the field by offering a convenient and efficient tool for educators while addressing the challenges associated with traditional manual grading methods.

The paper by Jain, Malik, and Bhatia [12] presents a robust image processing-based real-time optical mark recognition (OMR) system. The authors address the limitations of conventional OMR techniques by proposing a low-cost, portable model that can accurately detect marked responses on OMR sheets. They employ a series of image processing techniques, including edge detection using the Canny algorithm, blur detection with Discrete Fourier Transforms, contour finding using the Suzuki algorithm, and perspective transformation. The proposed model can handle practical challenges such as angle variation, poor lighting conditions, and blur, making it suitable for real-time grading systems. Notably, the model achieves high accuracy in processing OMR sheets, even when images are captured using mobile phones, eliminating the need for dedicated scanners. The research contributes to the field by offering an efficient and accessible solution for automating examination marking and other forms of marking, with potential applications in educational institutions and businesses.

The literature review for the "Optical Mark Recognition Evaluation System using Dual-Component Approach" paper by Dharmik et al. (2024) [13] provides a comprehensive overview of existing research and developments in the field of Optical Mark Recognition (OMR) systems. The review highlights various studies focused on enhancing OMR technology through the utilization of advanced image processing techniques and the integration of different hardware and software components. Maniar et al. (2021) and Gaikwad (2015) introduce Python-based OMR systems emphasizing dynamic thresholding and image processing methods, while Kowsalya et al. (2020) address the limitations of Optical Character Recognition (OCR) systems in the context of OMR. Raundale et al. (2019) explore OMR assessment techniques using ordinary 2D scanners, showcasing the broader scope of applications beyond traditional exam settings. Hasan et al. (2015) present a real-time, low-cost OMR system using a webcam, demonstrating its adaptability to user-designed forms. Additionally, Parul et al. (2012) and Anonymous (2018) contribute insights into advanced image processing and cost-effective OMR solutions. These studies collectively inform the development and implementation of the OMR system presented in the paper, highlighting the significance of OMR technology in revolutionizing data processing methodologies across various industries.

The paper "Approaching Computer Vision And Image Processing Technique For Optical Mark Recognition Sheet Scan And Verification" [14] presents a novel method for Optical Mark Recognition (OMR) using computer vision and image processing techniques. The literature review highlights several existing approaches in the field of OMR, including low-cost mobile OMR systems, template matching approaches, and software-based OMR response classifiers. These approaches emphasize the use of various technologies such as mobile devices, web cameras, and open-source libraries for OMR sheet evaluation and recognition. However, the paper introduces a comprehensive methodology that utilizes mobile phone camera images and implements edge detection, warp point generation, and Sobel operator refinement for accurate OMR sheet scanning and verification. The proposed method aims to address the limitations of existing techniques by providing a fast, low-cost, and efficient solution for OMR sheet processing, making it accessible to smaller educational institutions and individual educators.

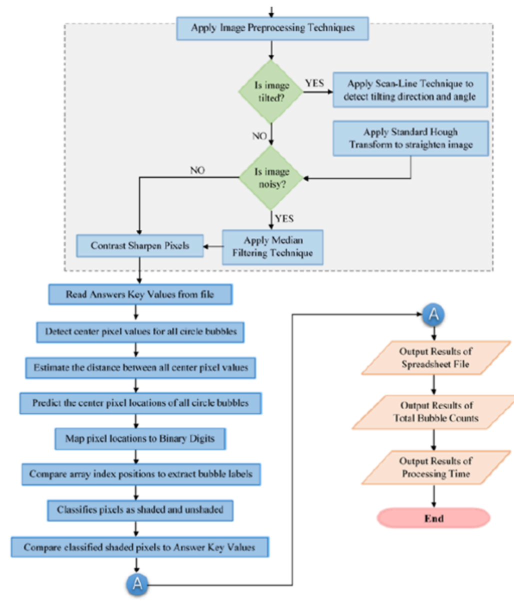


Figure 1: Recent Existing System

3. Proposed System

Figure 2: Proposed System - Diagram

1. Convert input OMR sheet image to grayscale for simplification.
2. Utilize contour detection to identify shaded or dark regions.
3. Apply Otsu's thresholding method to extract contours.
4. Analyze contours to detect bubble-shaped portions.
5. Determine bubble areas and dimensions, considering predefined thresholds.
6. Examine bubbles to identify marked answers using FFT analysis.

7. Map marked bubbles to corresponding question numbers and choices.
8. Evaluate accuracy by comparing marked answers to expected correct ones.
9. Provide visual feedback by highlighting detected elements on the input image.

Code:

The code was written using the library functions offered by OpenCV in Python.

Finding contours:

```
# Find the shaded/dark portions of the omr she
def find_contours(image):
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2G
    _, thresh = cv2.threshold(gray, 0, 255,
    cv2.THRESH_BINARY_INV + cv2.THRESH_OTSU)
    print("Otsu Thresholding")
    cv2_imshow(thresh)
    contours, _ = cv2.findContours(thresh,
    cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE
    return contours
```

Drawing the bounding rectangles for the shaded bubbles:

```
# Find the portions that form a bubble shape a
# draw bounding rectangle
def detect_bubbles(contours, image):
    bubble_data = []
    for contour in contours:
        area = cv2.contourArea(contour)
        if area > 50:
            x, y, w, h = cv2.boundingRect(conte
            if w > 10 and h > 10:
                bubble_data.append((x, y, w, h
                cv2.rectangle(image, (x, y),
                (x + w, y + h), (0, 255, 0), 2
    return bubble_data, image
```

Finding the bubbles marked as answer:

```
# Find the answers that are actually marked
def find_marked_answers(bubble_data, image, num_q):
    marked_answers = [None] * num_q
    print("x, y coords of bubbles and FFT value")
    for x, y, w, h in bubble_data:
        roi = image[y:y+h, x:x+w]
        gray = cv2.cvtColor(roi, cv2.COLOR_BGR2GRAY)
        _, binary = cv2.threshold(gray, 0, 255,
        cv2.THRESH_BINARY_INV + cv2.THRESH_OTSU)

        #cv2_imshow(binary)
        fft = np.fft.fft2(binary)
        fft_shift = np.fft.fftshift(fft)
        magnitude_spectrum = 20 * np.log(np.abs(fft_shift))

        # Find the maximum value in the magnitude spectrum
        max_val = np.max(magnitude_spectrum)
        print(x, y, max_val)

        # Apply inverse shift
        f_ishift = np.fft.ifftshift(fft_shift)
        img_back = np.fft.ifft2(f_ishift)
        img_back = np.abs(img_back)

        # Find the question no. and choice no.
        i = image.shape[0]
        j = image.shape[1]
        cdiv = (j // 4)
        nq = i // cdiv
        rdiv = (i // nq)

        # Find the darkest point
        minVal, maxVal, minLoc, maxLoc = cv2.minMaxLoc(img_back)

        # If max_frequency is above a threshold, then it is a marked answer
        if max_val > 215:
            marked_answers[y // rdiv] = (x // cdiv) + 1
            cv2.circle(roi, maxLoc, 5, (0, 0, 255), -1)

    return marked_answers, image
```

Score:

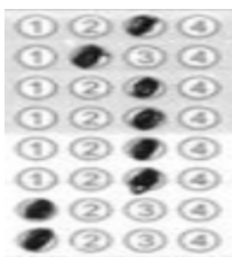
```
# Score based on marked answers
for i in range(len(answers)):
    if answers[i] == marked_answers[i]:
        score += 1
```

4. Experiments, Results and Discussions

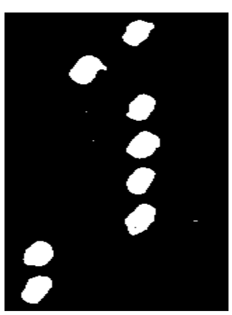
The experimental evaluation of the Optical Mark Recognition (OMR) system revealed a notable accuracy rate of 96.9% in interpreting marked answers from OMR sheets. However, the system encountered difficulties in processing sheets with only one question due to threshold value constraints, while working seamlessly for sheets with multiple questions. Out of 33 questions, improper bubble identification occurred in two instances, with one improper bubble erroneously identified as marked by the code, leading to interpretation discrepancies. The Otsu thresholding technique played a pivotal role in segmenting shaded or dark portions of the OMR sheet, facilitating contour detection and bubble identification. Despite its high accuracy, the presence of improper bubbles underscores the need for enhanced preprocessing techniques to address variations in sheet design and marking styles, improving accuracy and reliability. Future iterations of the system could benefit from refining bubble detection algorithms to mitigate such discrepancies, paving the way for more robust automated grading processes across various domains.

OMR Sheet 1:

Original:



After Otsu:



Shaded bubbles identified:

x, y coordinates of bubbles and FFT value

12 282 230.25050769897777

13 245 228.60283006982613

86 205 231.96095116774103

87 166 227.92670934721707

87 127 231.53489955366365

87 87 227.6961592437957

46 46 232.19378266805074

84 8 228.3799865387613

Marked bubbles identified:

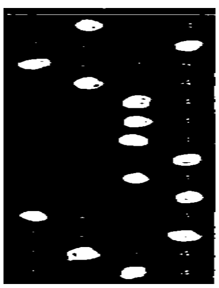
Marks: 2

Marked Answers: [3, 2, 3, 3, 3, 3, 1, 1]

OMR Sheet 2:

Original:

After Otsu:



Shaded bubbles identified:

x, y coords of bubbles and FFT value

88 525 224.96747619814602

48 485 229.62869595757718

124 451 228.71332758846552

12 412 222.1156790496224

130 371 227.1674941024326

90 334 220.18647372587114

128 296 224.5647780299649

87 256 221.49306067771892

91 219 224.96747619814602

90 177 223.80475566639265

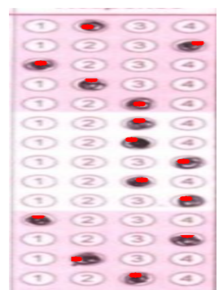
53 140 224.36034694853416

11 103 217.08939048400427

129 66 223.59236428984343

54 23 220.60402542630226

Marked bubbles identified:



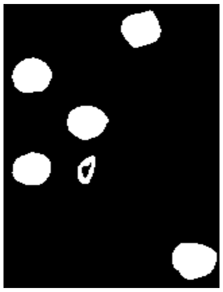
Marks: 2

Marked Answers: [2, 4, 1, 2, 3, 3, 3, 4, 3, 4, 1, 4, 2, 3]

OMR Sheet 3:

Original:

After Otsu:



Shaded bubbles identified:

x, y coords of bubbles and FFT value

125 202 244.2152327003261

55 128 214.5729870199836

6 125 239.09445004651565

47 86 240.3339252372503

6 45 240.63974159321867

87 5 241.0601774960631

Marked bubbles identified:

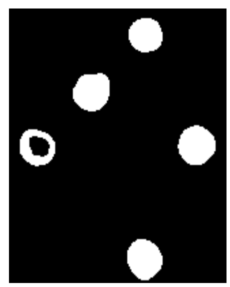
Marks: 2

Marked Answers: [3, 1, 2, 1, None, 4]

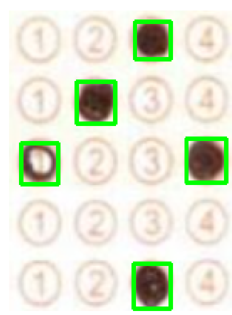
OMR Sheet 4:

Original:

After Otsu:



Shaded bubbles identified:



x, y coords of bubbles and FFT value

87 168 236.65665369433495

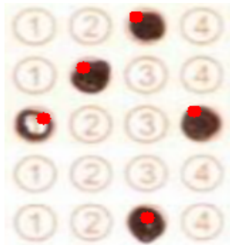
8 88 228.82321797481836

124 85 237.59715246723218

47 47 236.80425584028737

88 7 232.00773481480445

Marked bubbles identified:



Marks: 0

Marked Answers: [3, 2, 4, None, 3]

5. Conclusion

The research demonstrates the effectiveness of the proposed Optical Mark Recognition (OMR) system in accurately interpreting marked answers from OMR sheets. Despite encountering challenges in processing sheets with a single question and occasional improper bubble identification, the system's overall performance showcases its potential for automating grading processes with high accuracy. The findings underscore the importance of refining preprocessing techniques and bubble detection algorithms to enhance the system's robustness and reliability. Moving forward, future research efforts should focus on addressing these limitations and exploring innovative approaches to further advance OMR technology. By leveraging emerging methodologies and refining existing algorithms, OMR systems can continue to revolutionize the evaluation of standardized tests, surveys, and forms, ultimately streamlining processes and improving efficiency in various domains.

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