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Economical and Efficient Multiple-Choice Question Grading System using Image Processing Technique

Abdul Haris Rangkuti, Zefany Athalia, Tara E. Thalia, Caitlyn E. Wiharja, Abid Rakhmansyah

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Abstract: A common exam format that has gained popularity, especially in paper-based exams, is the multiple-choice question (MCQ), which is simple to use and quick to grade. MCQs are typically graded using a specialized apparatus that is expensive and inaccessible for the majority of teachers. The goal of this project is to create an image processing-based alternative that is more affordable and effective. The developed system makes use of a web camera to automatically display the students' grade and feedback analysis by capturing the answer key and the answers of the students. The Canny edge detection method was selected for analyzing the position of the answer on each question after system testing and method comparison. By using their phone or webcam, users would be able to grade exams effectively without the hassle of needing a specialized trained operator or machine. This study attempted to further develop previous studies by utilizing a video feed rather than an image feed to improve usability. This study concluded with a successful development of a reliable, effective, and affordable camera-based multiple-choice question grading system which has an accuracy of 94%. This research can be developed to facilitate multiple-choice questions with different formats.

Keywords*: *Computer Vision, Edge Detection, Image Processing, Multiple-Choice Question, Optical Mark Recognition

1. Introduction

Exam is an educational assessment to gain an understanding of students' comprehension of a particular subject. A type of exam, called the multiple-choice questions (MCQ) test, is widely used as an effective method to judge academic performance [1]. In these tests, a question or a statement is provided with four to five answer choices. Millions of students worldwide take MQCs each year for national entrance exams. This was done by filling in the circles in an answer sheet that will be graded using a specialized machine [2]. Thus this study is interested in developing a more cost-effective and efficient system to help the exam grading process for small institutes and teachers.

Although the use of computer-assisted assessment (CAA) could expedite the process of exam grading, especially for a large number of students, there are still certain drawbacks [3]. Automatic exam grading typically involves the use of costly OMR machines and software, which are also quite expensive and require a specialized operator to maintain and use properly. Not only that, but the current OMR technologies employ very complex hardware, making it very complicated to be used regularly [4]. According to one study [5] these drawbacks cause small institutes and individual teachers to be hesitant to purchase such machines and resort to manually grading answer sheets. Manual grading tends to be very tedious and on average an answer sheet takes at least 10 minutes. Not only that, but teachers could make mistakes when grading an answer sheet. This study will be focused on providing an alternative to traditional OMR machines by developing a low-cost, effective, and accurate tool to simplify the grading system by using image processing and OMR techniques and a web camera instead of a scanner. Teachers will be able to use their webcam to scan answer sheets and immediately see the correct answers, incorrect answers, and grades in real-time on their screen. Unlike other existing OMR alternatives already in the market, this research gains its novelty by using a real-time video feed instead of an image feed. This enables the users to move the papers to position with less hassle and optimize the grading process.

** Corresponding Author Email: rangku2000@binus.ac.id*

2. Literature Review

2.1 Introduction to OMR

The OMR scanners were originally developed in the 1950s with more desktop-sized models entering the marketplace in the 1970s. The original technology was called 'mark sensing' and used a series of sensing brushes in detecting graphite particles on a document that is passed through the machine [6] Optical Mark Recognition (OMR) is the process of reading and capturing human-marked data from documents and entering it into the computer [7]. This system works by utilizing the contrasting reflectivity at certain positions on a page; Marked areas reflect less light than blank areas. The most common use of OMR is to grade multiple choice exam answers and process responses to a survey form.

OMR uses a specific type of paper where respondents could tick out their choices using a dark pen or pencil. These marks will then be recognized using various algorithms and then graded by the answer key to the MCQs. This paper will break down the method used for non-traditional OMR techniques as we used a camera-based OMR.

2.2 Related Research

One study [1], conducted in 2011, developed a camera-based OMR that depends on allocating borders using the Hough transform and then skew-correction, followed by the normalization to a given size. Next, the tick marks are recognized by the allocation of the mask which wraps the answer area. This system has achieved high accuracy of 99.7%, a significant improvement over the conventional scanner-based method.

Another study [8], conducted in 2013, created a multi-core processors approach for camera-based OMR. With a 99.8% accuracy, this approach is great for a camera-based OMR, which has several problems regarding the image taken. However, the computation power of multi-core processors is wasted by developing sequential algorithms. The image processing algorithms have a high degree of parallelism and can be utilized efficiently. In conclusion, there's not much difference between single-core and multi-core processors in dealing with camera-based OMR.

2.3 Related Theory

2.3.1 Web Camera

Image-based OMR doesn't need to use special devices such as scanners for capturing the answer sheet images anymore. Nowadays, Camera-based technology gained a considerable amount of attention due to the widespread use of advanced low-priced digital cameras, webcams, and even phone cameras are becoming increasingly popular as an alternative imaging device [9] This camera-based technology makes a good solution for a small business and personal users. For example, a student or a teacher could use their PC, laptop, or phone test grading without buying any special devices. Moreover, this solution is highly flexible and portable. However, camera-based OMR has some challenges and problems which need special techniques and algorithms to solve these problems. The lighting problems, zooming and focusing problems, low resolution, and distortion are some of the main problems.[10]

2.3.2 Edge Detection Methods

Edge detection is one of the fundamental operations in computer vision with numerous approaches to it.
It is the process that attempts to characterize the intensity changes in the image in terms of the physical processes that have originated them. A critical, intermediate goal of edge detection is the detection and characterization of significant intensity changes.[11]

2.3.2.1 Canny Edge Detection

One of the approaches is the canny edge detection method which is a multi-stage edge detection algorithm created by John F. Canny in 1986. The Canny edge detector is widely used in computer vision to locate sharp intensity changes and to find object boundaries in an image. The Canny edge detector classifies a pixel as an edge if the gradient magnitude of the pixel is larger than those of pixels at both its sides in the direction of maximum intensity change.[12]

2.3.2.2 Laplacian Edge Detection

The Laplacian approach uses zero crossings in the image's second derivative to locate edges since the second derivative is zero when the first derivative is at its maximum.[13]

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Fig 1. Laplacian Kernel

2.3.2.2 Sobel Edge Detection

Sobel operator is one of the most commonly used detection methods and returns edges at points where the gradient of image intensity is maximum. The aim here is to find the absolute gradient of a point. Locations whose gradient value exceeds some thresholds are declared edge locations.[11]

$$G_x = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix} * A \quad \text{and} \quad G_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} * A$$

Fig 2. Sobel Kernel

2.3.3.4 Prewitt Edge Detection

Prewitt Edge Detection is a gradient edge detector that is similar to Sobel but differs in the middle value. If Sobel has 2 values shown 2 in each kernel, the Prewitt kernel has one uniform kernel.[13]

$$G_x = \begin{pmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{pmatrix} * A \quad \text{and} \quad G_y = \begin{pmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix} * A$$

Fig 3. Prewitt Kernel

2.3.3.5 Robert Edge Detection

Approximating the gradient of an image through discrete differentiation is achieved by calculating the sum of squares (SSD) of the differences between diagonally adjacent pixels.[13]

$$G_x = \begin{bmatrix} \mathbf{1} & \mathbf{0} \\ \mathbf{0} & \mathbf{-1} \end{bmatrix} \quad G_y = \begin{bmatrix} \mathbf{0} & \mathbf{-1} \\ \mathbf{1} & \mathbf{0} \end{bmatrix}$$

Fig 4. Robert Kernel

2.3.3 Image Processing Algorithms

In traditional OMR technique, the distortion of the sheet can be ignored because the sheet is thick enough to avoid the distortion when sheets pass through the OMR machine. But while using a plain thin sheet (70gsm or less), the distortion of the sheet becomes a critical problem in mark recognition. [14]
In camera-based OMR, the image taken might be distorted which can cause OMR recognition error. These distortions are required to be corrected in OMR processing. The method used is:

2.3.3.1 Image Enhancement

The process of adjusting digital images so that the results are more suitable for display or further image analysis [15]. For this paper, we used the Gaussian filter, which helps reduce noise and improve edge detection accuracy.

3. Methods

The system was made possible with the help of opencv and ndimage scipy. Opencv is a well-known computer vision library that offers a wide range of image processing and analysis functions, while ndimage scipu is a library that offers tools for analyzing and manipulating multi-dimensional arrays.
To develop OMR software using opencv and ndimage scipy, the first step is to capture an image of the document using a camera or scanner. This image will then be processed using image processing techniques such as edge detection, thresholding, and morphological operations to identify and extract the marks.
Overall, opencv and ndimage scipy provides a reliable and efficient way to read and interpret on a document and provide valuable information that could be processed further.

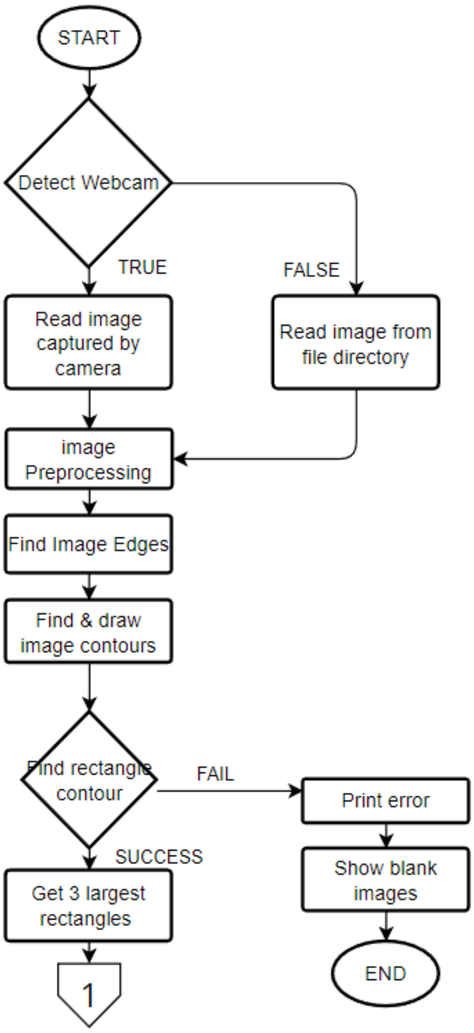

Fig 5. Image Preprocessing Flowchart

Fig. 5, Fig.6, and Fig. 7 explains the system's working in detail.

3.1 Image Preprocessing

Fig. 5 depicts the image preprocessing and rectangle detection process. The program starts by detecting the availability of the user's webcam, if it is unavailable then the user needs to manually input a scanned image.

With the camera, the program will scan the image and process it by resizing, converting to grayscale, and applying a Canny threshold to create a binary image and finding the edges.

This system uses the Canny Edge Detection because it is often considered the best edge detection method for OMR, and its ability to accurately detect and distinguish edges of objects in an image.

Next, the program will use morphological operations to clean the image and isolate the marks. Finally, it uses ndimage's label function to count the number of marks in each connected component in the image.

3.2 Image Grading

After Doing the preprocessing phase, the warped image will be divided into rows and columns. The 2 largest columns will be marked as the answer columns. The answer is then determined by counting the columns with the most pixels in each row by using the threshold. If the answer matches the answer key on our database, it will be marked "correct" and a value of 1 will be given. Otherwise, it will be marked as "incorrect" and given a value of 0. The grades will then be calculated from these evaluations and will move on to the next phase. The grading phase is depicted in Figure 6.

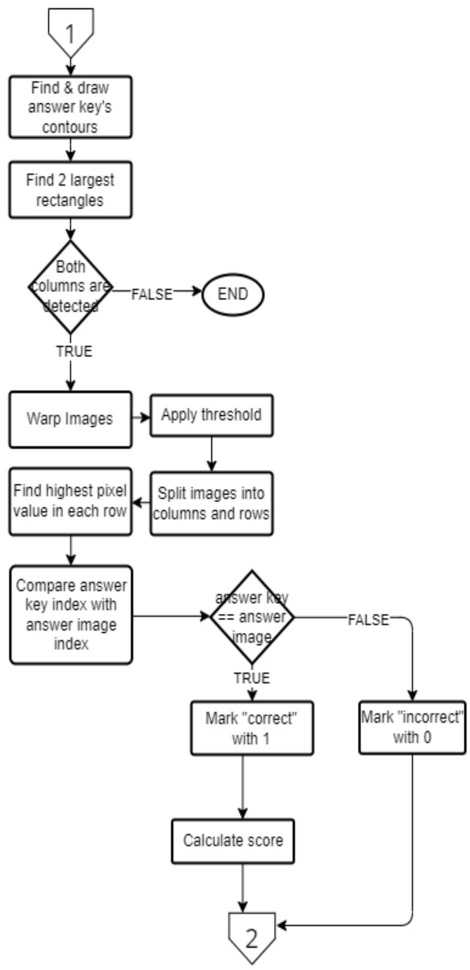

Fig 6. Image Grading Flowchart

3.3 Image Stacking & Displaying

The image displaying phase is shown in Fig. 7. In this phase, the grading analysis will be overlayed on the original image, with red dots denoting "incorrect" and blue dots denoting the supposed "correct answer" if the answer is incorrect, and green dots denoting "correct". All the original, grayscale, contour, edge detection, rectangle detection, and final result images are then stacked and displayed as a single final image that can be saved.

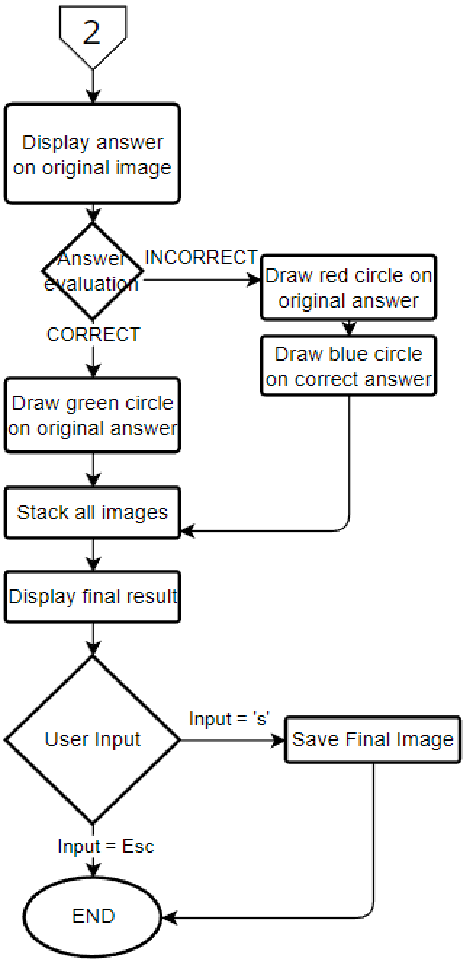

Fig 7. Image Displaying Flowchart

4. Result and Discussion

4.1 High Fidelity Prototype Result

Fig. 8 depicts the answer key, where the user has scanned the answer key for an exam. This answer key will then be used by the system to grade each student's answers. Fig. 8 also depicts the answer sheets that are scanned by the user. The system works by using a real-time camera-based video feed, so the users don't need to scan and capture each answer sheet manually.

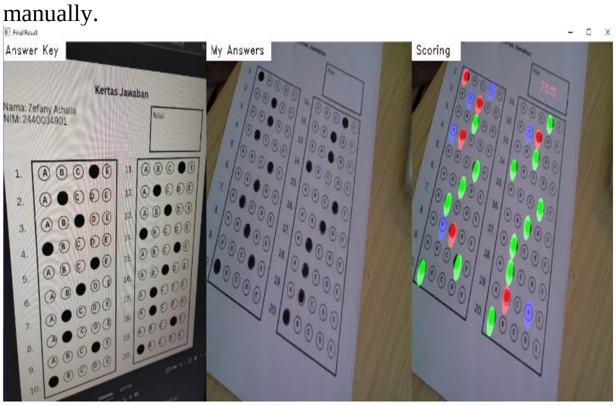

Fig 8. Scanned answer key and answer sheet

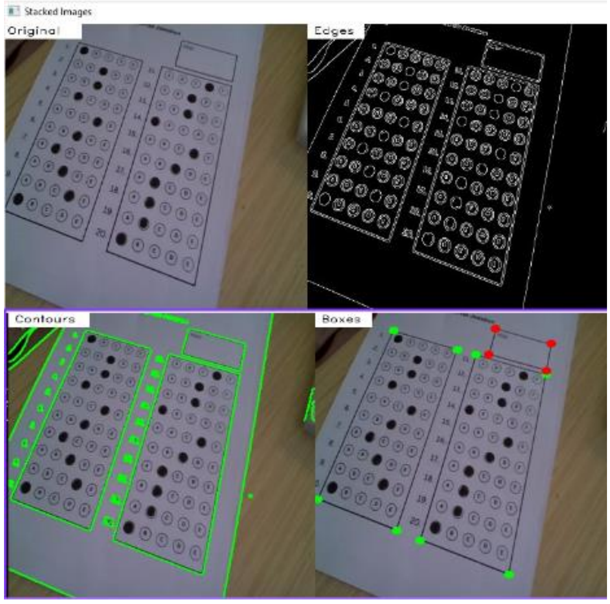

Fig 9. System's image processing.

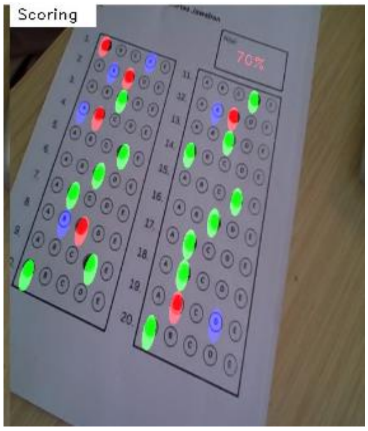

Fig 10. System's final result.

Fig. 9 depicts the system's image processing process. This process starts by finding the edges and contours of each paper, and through these edges the system will be able to find the answer columns.

Fig. 10 depicts the final result of the system, where the grading analysis and score are overlaid on the original answer sheet.

4.2 Accuracy Testing

Students were asked to fill in exam papers in the appropriate circle, the students were free to use any method of marking and any type of pen. The answer sheets were then gathered and put under the webcam. The results were calculated by the program almost instantly after the papers were in sight.
The calculation formula that was used for calculating the system's accuracy is as can be seen in equation (1); Table I. shows the testing results in detail. Through accuracy testing, it was found that the system has an accuracy percentage of 94%.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

Table 1. Accuracy Testing Results

Answer Number (20 Items)	*True Positive (TP)*	*False Positive (FP)*	*True Negative (TN)*	*False Negative (FN)*
1	1	1	17	1
2	4	2	13	1
3	5	0	15	0
4	3	0	17	0
5	2	0	16	2
6	1	1	15	3
7	1	2	16	1
8	3	0	17	0
9	1	1	17	1
10	7	0	13	0
11	10	0	10	0
12	17	1	2	0
13	13	0	7	0
14	18	0	2	0
15	15	2	2	1
16	8	0	11	1
17	15	1	4	0
18	14	1	4	1
19	17	0	3	0
20	15	0	5	0
Total Items: 400	Total: 170	Total: 12	Total: 206	Total: 12

4.3 Discussion

An enhanced multiple-choice grading system was developed in this study to improve exam paper grading accessibility and flexibility. To improve exam grading's usability and ease of use, several features were created. Users could instantly save the answers by using the webcam to capture the answer key. Then, users could scan numerous answer sheets simultaneously under the webcam. The answer sheets could be stacked, put in front of the webcam, and then each sheet is taken out one at a time. Each displayed answer sheet will automatically have the scores overlaid and saved.

The evaluation's positive outcome indicated that a camera-based multiple-choice question grading system is feasible, promising, and beneficial. This method offers a fresh alternative to exam grading and gives teachers access to a more efficient and dependable system.

5. Conclusion

Using image processing techniques, a flexible and low-cost camera-based multiple-choice question grading system was successfully created. The answer key and answer sheets are captured in real-time by this system using a webcam through a video feed. Additionally, this system has the ability to automatically overlay the displayed answer sheet with student grades and corrections. System testing revealed that the system has a 94% accuracy rate. A few requirements for this system include using a special paper format with two answer columns and a score box is required for this system, and the webcam must be able to see every corner of the answer columns and score box. This research could be further developed by developing an image processing system that can adapt to various paper formats and improving the accuracy and reliability of the system.

Biography

Abdul Haris Rangkuti is a lecturer and a researcher at School of Computer Science in Bina Nusantara University. He received the B.S. degree in Management Informatics and the M.Sc and Ph.D Degree in Computer Science both from Institut Pertanian Bogor and University of Gadjah Mada in 1996, 2006 and 2020. His research is interests' multimedia processing (image, audio, video processing), computer vision, and medical disease recognition. He involved in international project such us from ADB and Word Bank as analyst system and team leader. He ever carried out some project from department / minister as Analyst system or Team Leader.

Zefany Athalia was born in Bandung, Indonesia on 24 April 2002. She is currently pursuing her Bachelor of Computer Science (BCS) from Bina Nusantara University, Bandung, Indonesia. Her research interests include computational neuroscience, linguistics, and bioinformatics. In 2022 she received a Best Paper Award from the IEEE 7th International Conference on Information Technology and Digital Applications (ICITDA) for her paper titled "Development of an Augmented Reality-Based Educational Game to Aid Elementary School Learning Using Scrum".

Tara E. Thalia, born in Bandung, Indonesia in 2001 is currently attending Binus University as a computer science student, now in her second year. She graduated from Santo Aloysius High School in 2019 where she majored in science, where she learned a fair amount of computer programming and writing scientific research. Her areas of interest include linguistics, examining cultural data, and now she is doing self-study to become a skillful developer.

Caitlyn E. Wihardja, was born on November 18, 2000, in Bandung, West Java, Indonesia. At the age of 20, she graduated from Yahya Christian School with a Science major in 2020 and is currently attending Bina Nusantara University, Bandung, as a Science Computer student. Her area of interest revolves around game development and web designs

Abid Rakhmansyah, born in Banjarnegara, Indonesia in 1999 is currently attending Binus University as a computer science student, now in his second year. He graduated from Senior High School 1 Banjarenagara in 2017 where he majored in science. His current research interests include exploring ways to improve the efficiency and generalization capabilities of AI systems, with a particular focus on applications in the healthcare industry. In addition to his research, Abid has also won 3rd place in SOCS AI Competition hosted by Binus University.

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