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Optical Mark Recognition using Modify Bi-directional Associative Memory

Rusul Hussein Hasan[1], Inaam Salman Aboud [2], Rasha Majid Hassoon[3], Ali saif aldeen Aubaid Khioon [4]
University of Baghdad, Iraq[1, 3 ,4], Al- Mustansiriya University, Iraq[2]

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Corresponding Author*:
russl@colaw.uobaghdad.edu.iq

ABSTRACT

Optical Mark Recognition (OMR) is an important technology for applications that require speedy, high-accuracy processing of a huge volume of hand-filled forms. The aim of this technology is to reduce manual work, human effort, high accuracy in assessment, and minimize time for evaluation answer sheets. This paper proposed OMR by using Modify Bidirectional Associative Memory (MBAM), MBAM has two phases (learning and analysis phases), it will learn on the answer sheets that contain the correct answers by giving its own code that represents the number of correct answers, then detection marks from answer sheets by using analysis phase. This proposal will be able to detect no selection or select more than one choice, in addition, using MBAM make it timeless because it will deal with a complete answer sheet, it no need to extract the answer boxes from the answers sheet. The proposed OMR exhibits accuracy is 99.998% in the recognition of marked and non-marked.

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التعرف البصري على العلامة باستخدام تعديل الذاكرة النقابية ثنائية الاتجاه

رسل حسين حسن — جامعة بغداد
انعام سلمان عبود — الجامعة المستنصرية
رشا ماجد حسون — جامعة بغداد
علي سيف الدين عبيد — جامعة بغداد

الملخص

يعد التعرف الضوئي على العلامة (OMR) تقنية مهمة للتطبيقات التي تتطلب معالجة سريعة وعالية الدقة للنماذج الكبيرة المملوءة يدويًا. الهدف من هذه التقنية هو تقليل العمل اليدوي والجهد البشـــري والدقة العالية في التقييم وتقليل الوقت في التصـــحيح الالكتروني. اقترحت هذه الورقة البحثية باســـتخدام تعديل الذاكرة النقابية ثنائية الاتجاه(MBAM) ، حيث تعمل MBAM بمرحلتين (مراحل التعلم والتحليل)، وســـوف تتعلم على أوراق الإجابة التي تحتوي على الإجابات الصـحيحة من خلال إعطاء الكود الخاص بها الذي يمثل عدد الإجابات الصـحيحة، ثم علامات الكشـف من أوراق الإجابة باسـتخدام مرحلة التحليل. هذا المقترح سـيكون قادرًا على اكتشـاف عدم تحديد أو تحديد أكثر من خيار واحد، بالإضـافة إلى ذلك، باسـتخدام MBAMتقليل الوقت لأنه سـيتعامل مع ورقة الإجابة الكاملة، فلا داعي لاسـتخراج مربعات الإجابات من ورقة الإجابات. تبلغ دقة النتائج للطريقة المقترحة ٩٩,٩٩٨٪ في التعرف على العلامات المؤشرة وغير المؤشرة.

الكلمات المفتاحية: الذاكرة الترابطية، معالجة الصور، قارئ العلامة الضوئية، تعديل الذاكرة النقابية ثنائية الاتجاه.

Introduction

Optical Mark Recognition (OMR) technology has been improving in recent years; it's one of the most important trends in the education system and has been widely used in the field of education (in schools, colleges, and classes). This technology provides convenience to teachers in the evaluation of student answers, and the management of the exam becomes much easier, more powerful, and cheap. It is used to scan marked sheets to detect the presence or not of the mark at the predetermined position. [1, 2]

OMR technology is used for inserting data digitally into the computer, like (assessments, multiple choice question tests, enrolment, class evaluation sheets, and surveys, etc.). The marker was placed at predetermined positions on the answer sheet with a pen or pencil as a response to questions or tick list prompts that can be read by the OMR.

OMR is very useful when a large amount of data is to be collected from several sources at the same time and processed in a short period of time [3]

The technology of OMR is also called a mark sense or Optical Mark Reader. This technology is useful to extract data from marked shapes like fill-in (circles, squares, triangles, rectangles, and shapes) as well. The most common applications of OMR are used in schools, research centres, industries, and universities.[4]

Since paper is vulnerable to diverse climate changes, maintaining it for an extended period of time is difficult (fire, moisture, etc.) additionally, individuals must manually enter each score in a new Excel sheet or file. In the modern era of automation, The Multiple Choice Question (MCQ) is mostly used to evaluate the academic performance of students in schools. MCQ is an important part of the education system. The responses to Multiple Choice Questions exams are recorded in the OMR answer sheet. OMR answer sheets must be evaluated by separate, specialized machines for scanning and marking. These machines require special sheets, which are more expensive than regular sheets. These machines require special, more expensive answer sheets than the standard answer sheets. [4, 5]

The main contribution of this paper is the use artificial intelligence technique to OMR called Modify Bidirectional Associative Memory (MBAM), this technique can detect no selection or select more than one choice, in addition, no need to extract the answer boxes from the answers sheet this lead to real-time work

The layout of the paper presents the background of the methodology used to implement the proposed OMR module. In addition, focuses on the methodology that is used to achieve the goals of this paper, and finally presents the analysis and discussion of the results obtained from the proposed OMR module.

Related Work

Ms. Sumitra B. Gaikwad (2015), suggested a system to create OMR sheet scanning based on image processing. Observing how many competitions are being held as entrance exams there are multiple choice questions on that test. The appropriate response for each question should be entered in the circle box by the pupils. The examiner is able to determine the right response to the questions through the examination or inspection phase that is presented. [1]

Rusul Hussein Hasan, Emad I Abdul Kareem (2015), proposed OMR model uses an associative memory algorithm called Modify Multi-Connect Architecture (MMCA), this proposed extract the answer boxes from the answers sheet and also able to detect more than one or no selected choice, its work in two phases: learning and converge phases. [8]

Seng Cheong LokeID and et al., (2018), this paper proposed a new method for OMR by improving this technology depending on pixel counting and simple thresholding, the main advantage of this improving is maintaining high accuracy that is sufficient for scientific applications and used under a variety of conditions. [11]

Amit Kumar, Himanshu Singal, Arnav Bhavsar (2018), this paper proposed an algorithm based on image processing, that can evaluate and read the scanned OMR without no special hardware required It will rescind the use of special OMR sheets. The answers will be recorded in a normal sheet is enough for evaluation. This system cares about brightness, color, and rotation in OMR sheet images [12]

Afifi, M., Hussain, K.F. (2019), this paper proposed a method to reduce the constraints placed on assessments by multiple-choice questions (MCQ). Also, take the response boxes out of the answer sheets using an image registration technique. This method the issue from a different angle by training a machine learning classifier to identify the class of each extracted answer box, in contrast to other systems that rely on straightforward image processing processes to detect the extracted answer boxes (i.e., confirmed, crossed out, or blank answer). This allows us to distinguish between selected (i.e., confirmed) and canceled replies while handling a range of shade and mark patterns (i.e., crossed out). All currently used machine learning approaches need a lot of instances to train a categorization model. [13]

Pooja Raundale and et al., (2019), this paper proposed to build a system dependent on a webcam, which gets automatically the image answer sheet and will evaluate all responses and displayed results, determining the score and total percentage. This paper uses OpenCV to extract the image and apply content-filtration to the image processing algorithm. [14]

Asmaeil Ammarah Abdullah BALQ (2019), this research, is aimed to develop the Optical SignaL Recognition (OIT) system with image processing technology. In line with the targeted purpose, a system was designed for reading answer sheets of multiple choice test exams based on image processing and the results obtained with the system application were evaluated. The system was developed using the Visual Basic (VB) programming language with Microsoft Visual Studio 2013. The process of reading and evaluating exam papers is an important activity that takes a significant part of the trainers' time. It is extremely important that this process is carried out correctly and without errors in terms of evaluating education. Different methods have been used to detect one or more options marked in the implemented system. These methods are based on the optical answer key template and the calculation of the key point. [15]

Mondal, S., De, P., Malakar, S. and et al., (2023) In this paper, propose a lightweight Convolutional Neural Network (CNN) model called OMRNet that is based on transfer learning and can categorize response boxes on any generic OMR test sheet. The OMRNet is intended to categorize the response boxes into confirmed, crossed-out, and empty categories, in contrast to most existing systems that rely on image processing algorithms to distinguish extracted answer boxes into two classes: confirmed and empty. In other words, OMRNet makes it easier to mark out questions that have already been answered, eliminating the rigidity of MCQ test templates. On top of a MobileNetV2 backbone, we've constructed OMRNet, which is connected to four completely connected layers with the proper dropouts and activation features in between. On the Multiple Choice Answer Boxes dataset, we tested OMRNet. [16]

Kanjalkar, P.and and et al., (2023) It is intended that the user will upload a single file containing all of the responses and tabulate the outcomes. The system analyses the student's responses using a variety of image processing techniques, displaying the grade and the input image along with the correct, incorrect, and actual answers in green, red, and yellow hues, respectively. Additionally, the user has access to an interactive dashboard that displays numerous metrics related to the performance of the students. Users can select the number of questions, the number of choices, the marks per question, and other features in this implementation, which makes it special. In this study, a practical method for accurately scanning OMR sheets without scanners is presented. [17]

Modify Bidirectional Associative Memory (MBAM)

Artificial intelligence is a field of study that encompasses a number of novel approaches and techniques for programming computer systems that are used to create systems that mimic some aspects of human intelligence and enable them to perform deductive operations on facts and laws stored in the computer's memory. Or to put it another way, artificial intelligence is the study of how to create a machine, namely a computer. Operations are carried out that correspond to mental processes in humans. [9,10]

One of the most popular neural network models for heterogeneous association and optimization problems is the bidirectional associative memory (BAM) network. The BAM has a number of restrictions, including shift and scaling issues, problems with local minima, finite noise ratio, and finite stored patterns. The MBAM will change the network structure, learning procedures, and convergence to enhance the bidirectional associative neuronal memory (BAM) network. By removing most of the restrictions, this change improves the bidirectional associative memory (BAM) neural network's performance. [6, 7, 9]

In addition to that improving its efficiency by reducing the size of the network and the size of the weight. As a result of the above, the ability to noise will be increased, as well as the acceleration and convergence of learning. The evaluation process proved that the (MBAM) network can learn and recognize (100) patterns of

different sizes and acceptable rates of noise and overcome most of the limitations of BAM except for the problems of transformation and up scaling. According to the learning stage, MBAM storage capacity has reached 100 patterns and is still working efficiently. In addition, the size of the matrix weights became smaller (i.e. four matrices), and the size of the MBAM network structure (four neurons) is determined with any pattern size (i.e. it will not depend on the size of the pattern). MBAM uses a bipolar representation, where each element will be either 1 or -1. MBAM architecture is shown in Figure 1. [6, 7]

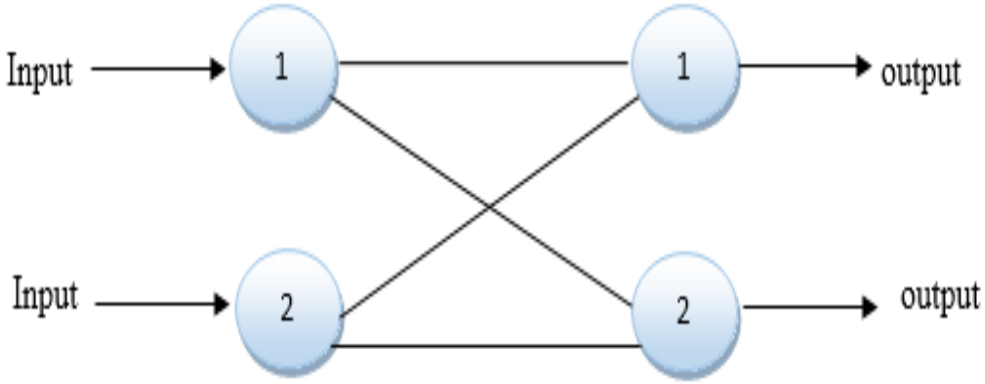

Figure 1: MBAM [6]

Learning Phase

Algorithm 1 shows the learning phase algorithm, where the input for this phase is the training pattern with it is codes and the output lookup table for all training patterns. [6]

Algorithm 1: Learning Phase Algorithm. [6]

Input: training patterns p with code c, n.
Output: lookup table for all n corresponding stored patterns.

Step_1: Repeat step_1.1 and step_1.2 to the end of training pattern p with code c:

Step_1.1: Divide the training pattern p to n vectors v with length two.

Step_1.2: For each vector v, repeat step_1.2.1, step_1.2.2 and step_1.2.3:

Step_1.2.1: Assign the weight for each n vectors v, weights matrix w as follows:

$$w_i = v_i * c$$ Where: c is code

Step_1.2.2: Assign the stored vector's weight svw as follows:

$$svw = f(Decode(v)) \begin{cases} 0 & \{means w0 \\ 1 & \{means w1 \\ 2 & \{means w2 \\ 3 & \{means w3 \end{cases}$$

Where: Decode is a function to convert the binary number to decimal number.

Step_1.2.3: Save svw for this vector in the lookup table.

Step_2: End

Convergence Phase

Algorithm 2 and **Algorithm 3** show Convergence phase algorithm are pattern to code and code to pattern respectively, where the output of the converge phase based on the result of learning phase **[6,7]**

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Algorithm 2: Convergence Pattern to Code [6]

Input: n of unknown' patterns p and lookup table.
Output: Convergence code *c*.

Step_1: Repeat **step_1.1** and **step_1.2** until the end of unknown pattern p:

Step_1.1: Divide the unknown pattern p to n vectors v with length two.

Step_1.2: Sum up the energy function for all n vectors v in the unknown pattern each with its corresponding vector in the stored patterns:

$$\boldsymbol{ep = -0.5 * \sum_{i=1}^{n} (y_i)^2}$$

Where *n* is the number of vectors and y_i is : $\boldsymbol{y_i = v_i * svw_i}$

Step_2: Determine the stored code number $minc$ with the minimum energy function to converge the unknown pattern towards it:

$$\boldsymbol{minc = min\ (ep)}$$

Where the min function is to determine the minimum energy function in ep array.

Step_ 3: End.

Algorithm 3: Convergence Code to Pattern [6]

Input: *n* of unknown codes *c* and lookup table.
Output: Convergence pattern *CP*.

Step_1: Repeat **step_1.1** until the end of the lookup table:

Step_1.1: Find energy function ep:

$$ep = -0.5 * \sum_{i=1}^{n} x_i . c$$

Where: $x_i = y_i * svw_i$ *and* $y_i = c * svw_i$ *and* c: is an unknown code
svw: is matrix weights stored in lookup table.

Step_2: Determine the stored pattern number $minp$ with the minimum energy function to converge the unknown code towards it:

$$minp = \min\ (ep)$$

Where the min function is to determine the minimum energy function in ep array.

Step_3: **Build the final converge pattern *cp:***

$$\boldsymbol{cp = svw_{minp} * c}$$

Step_4: End.

Proposed Method

Figure 3 and **Algorithm 4** show the architecture of the proposed OMR. The proposed method consists of two stages (pre-processing and detection stages). The answer sheet model shows in **Figure 2.**

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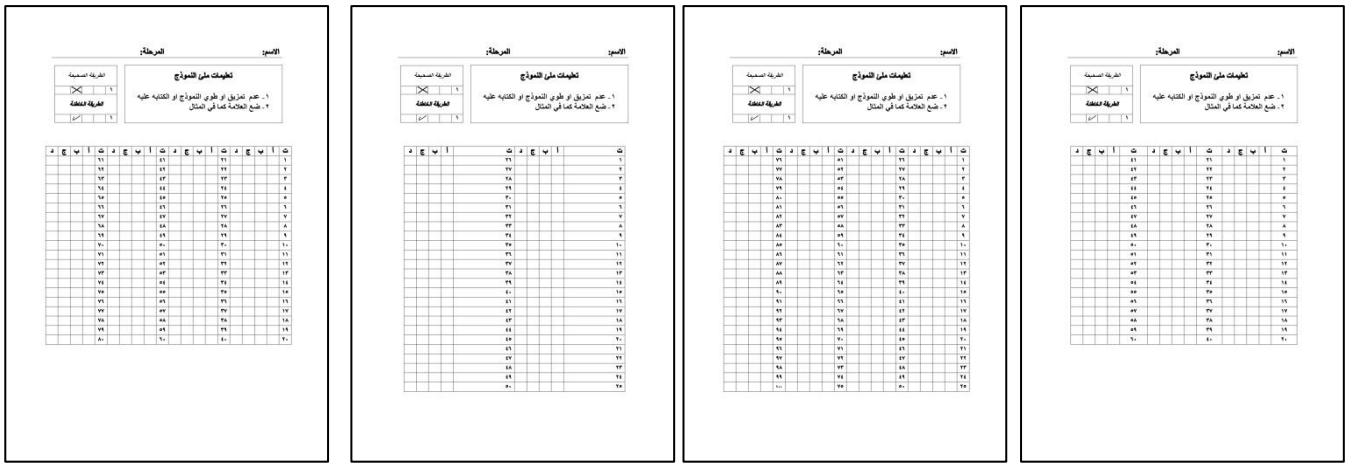

Figure 2: Blank Model for the Answer sheets

Algorithm 4: Algorithm of the Proposed OMR

Input: Answers sheet
Output: Student Score
Step_1: Answers sheet acquisition by using ADF Scanner with JPG **Step_2:** Use Pre-processing steps (Step_2_1, Step_2_2, Step_2_3, Step_2_4) to make scanned answer sheet more suitable as following: **Step_2_1**: Convert answer sheet to Binary by using thresholding method **Step_2_2:** Rotate the answer sheet to the original location, because when the answer sheet was scanned with a scanner, by using Hough transform algorithm and bilinear interpolation algorithm **Step_2_3:** Splitting image answer sheet by using horizontal and vertical projected, used to located answer area **Step_2_4:** Convert answer sheet to bipolar representation because MBAM dealing with this representation. **Step_3:** Answer Sheet Detection by apply algorithm 2 (Convergence Pattern to Code) End

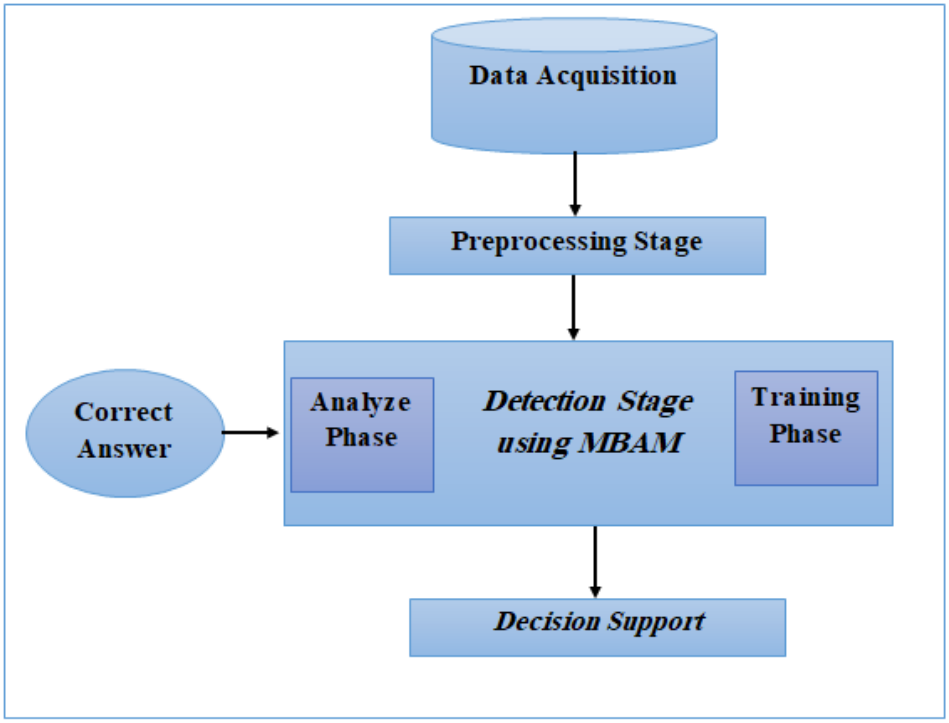

Figure 3: Flowchart of Proposed Method

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Data Acquisition

The answers sheet is transferred from the scanner to the computer with JPG (which is smaller in size compared to other formats such as PNG and BMP) format by using Automatic Document Feeder (ADF) scanner. The captured images include:

Pre-processing Stage

The pre-processing stage includes the following steps to make the scanned answer sheet more suitable for the next stage:

Binarization

Binarization refers to the conversion of answer sheets to binary, firstly, The scanned answer sheets are contained color format, these answer sheets are converted to grayscale format, and by using the thresholding method convert to binary.

Rotation

The main objective of this step is to rotate the answer sheet to the original location. Because when the answer sheet was scanned with a scanner, it was rotated at different angles. To achieve that, first by using Hough transform algorithm compute the correct angle, and then rotate the image answer sheet to the normal location by using a bilinear interpolation algorithm with the correct angle [18]. **Figure 4** shows rotation operations for the image answer sheet.

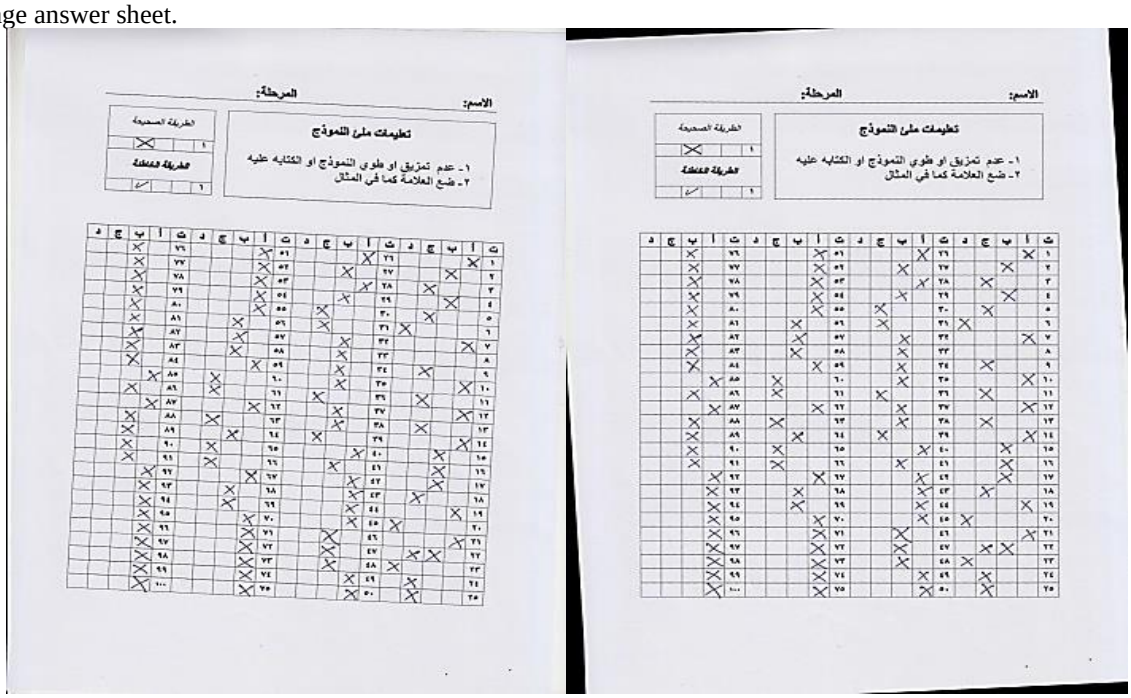

Figure 4: Image Answer Sheet before / after Rotation Operations

Answer Area Allocation

This step is important for splitting the image answer sheet by using horizontal and vertical projected, used to locate the answer area, by Compute vertical and horizontal projections, by counting white pixels in each column and row, **Figure 5** shows cropping horizontal and vertical projections for the image answer sheet, In additional it's no need to extract the answer boxes from answers sheets, it will deal with complete answer sheet in next stage.

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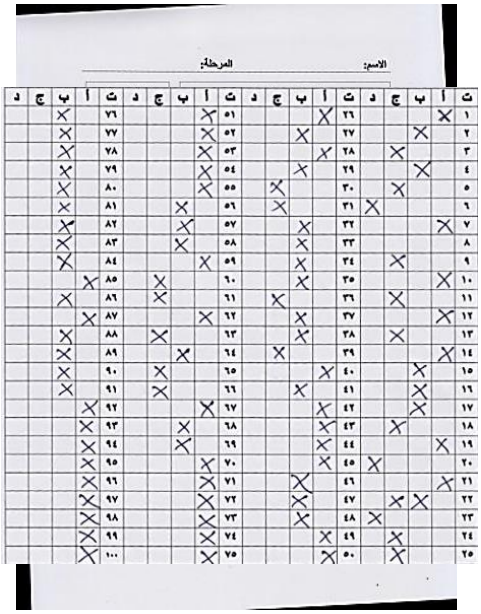

Figure 5: Answer Area Allocation before / after Cropping

Bipolar Representation

The answer sheet should be converted to bipolar representation (each pixel in the image should be 1 or -1) because MBAM deals with this representation.

Answer Sheet Detection

Use Modify Bidirectional Associative Memory (MBAM) to detect marks for answer sheets with two phases its learning and converge phases as shown in **Figure 6**.

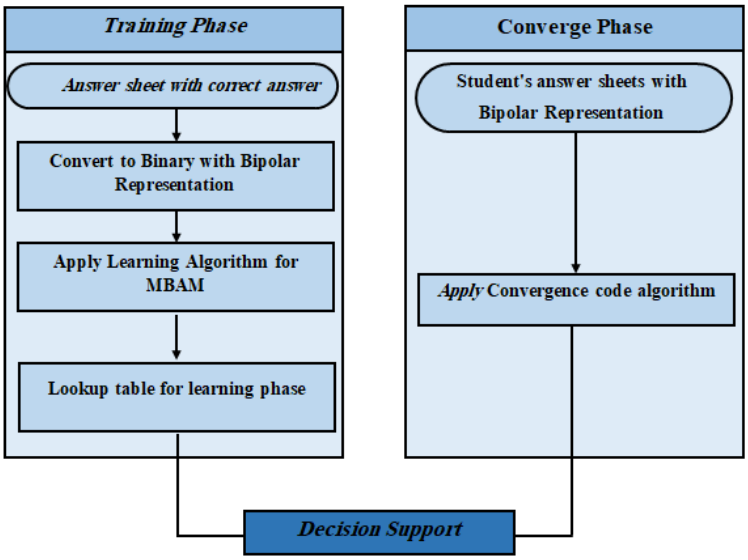

Figure 6: Learning and Converge Phases for MBAM

The learning Phase will be applied on a set of sheets that have correct answers with codes that represent a number of correct answers. **Figure 7** showed some sheets with its codes **.**

While in Converge Phase will apply to code the algorithm for the student's answer sheets by matching the student's answer sheets with a lookup table, which is established through the training phase.

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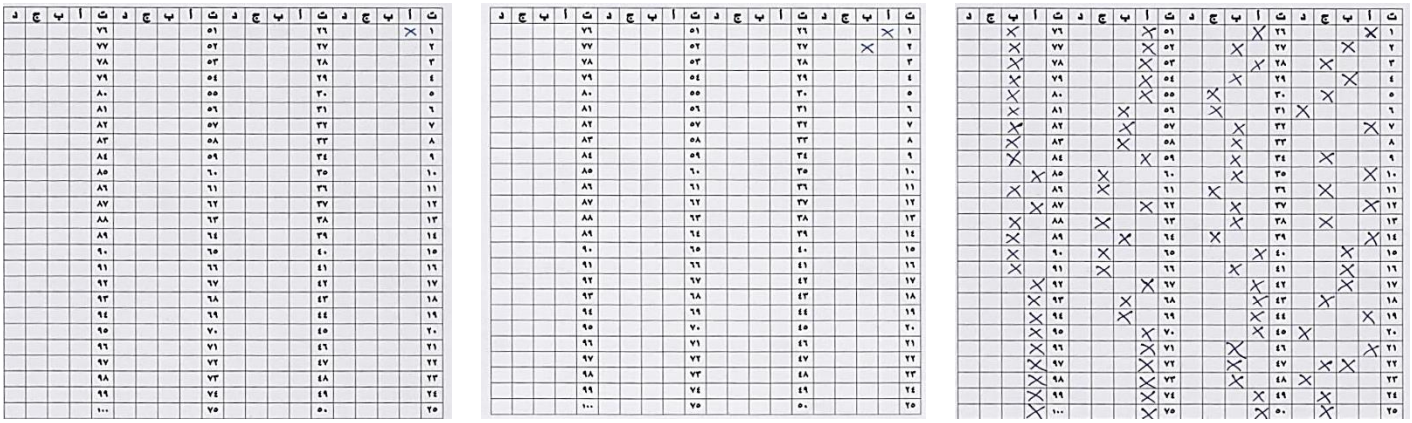

Figure 7: Some Sheets with its Codes

Results Discussion and Analysis

To evaluate the performance and stability of the proposed OMR module shown in **Table 1** and **Figure 8**, tested with four different types of answer sheets (each type consisting of 250 samples), the total number of samples is 1000 (where the total numbers of questions are 72500), the average accuracy resulted was 99.988%. This proposal will be able to detect no selection or select more than one choice, in addition, using MBAM make it timeless because it will deal with a complete answer sheet, it no need to extract the answer boxes from the answers sheet. The average time of processing a sheet is less than 30 seconds. The experiments showed only 8 answers were unrecognized from the total number of questions (i.e. the 72500 questions).

Table 1: Different Types of Answer Sheets with Accuracy Result.

Type of answer Sheet	No. of Answers Sheet	No. of Question	Total No. of Answer	Recognized	Unrecognized	Recognition Rate
I	250	50	12500	12500	0	100%
II	250	60	15000	15000	0	100%
III	250	80	20000	19997	3	99.985%
IV	250	100	25000	24995	5	99.98%
Total	1000	290	72500	72492	8	99.988%

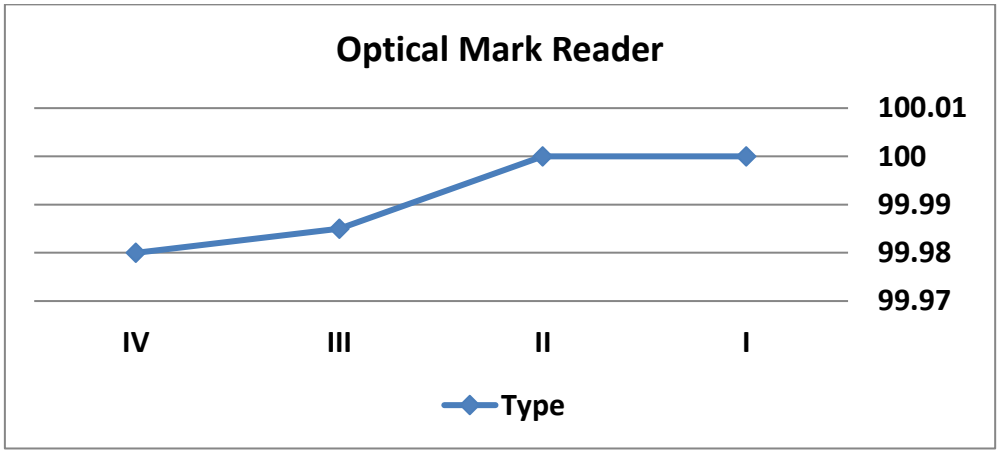

Figure 8: Show Accuracy Result for each Type.

Comparison with Other Works

The related work in the section above shows that there are some papers has a similar target to the present paper. These papers used the artificial intelligent technique to detect marks. Therefore, it is useful to compare it with the proposed OMR module. This comparison focused on compare with the accuracy result for these papers as shown in **Figure 9.**

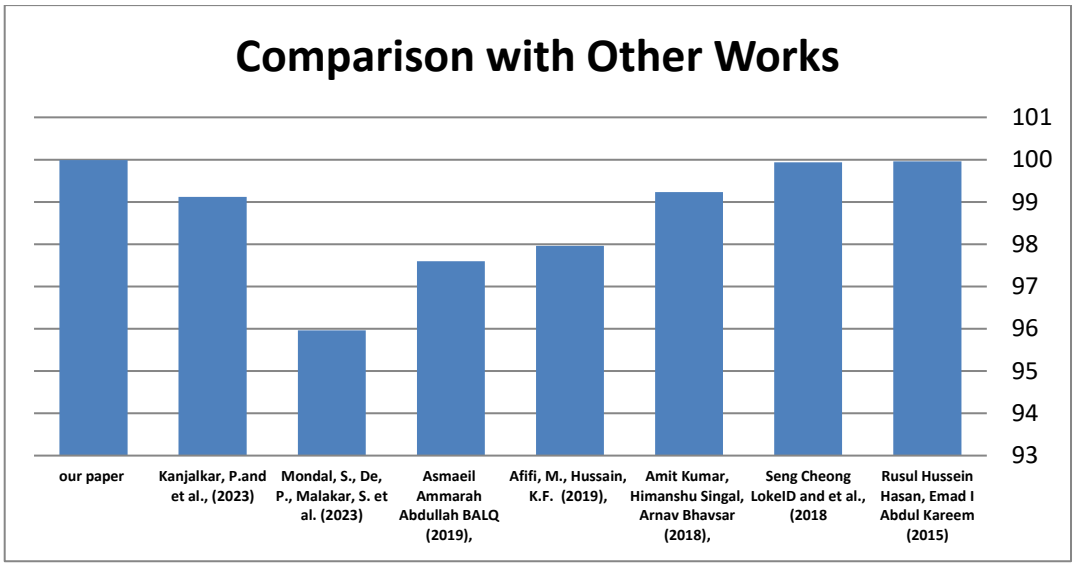

Figure 9: Average accuracy Comparison with Other Works.

Conclusion

The OMR module has been evaluated using an image answer sheet taken by the scanner, which is the content of the correct and incorrect answers. The total number of image answer sheets is 1000 with JPG format. In this paper no need for an OMR scanner used an ADF scanner to scan the answer sheet, and then used it as input to the OMR module. Experimentally, the proposed system has been able to deal with answer sheets even with noise (i.e., unexpected bad printing or scanning, pen writing, etc.). This proposal will be able to detect no selection or select more than one choice, in addition, by using MBAM make it timeless because it will deal with a complete answer sheet, it no need to extract the answer boxes from the answers sheet. The module shows accuracy is 99.998%.

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