On Image Based Fast Feedback Systems for Academic Evaluation

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***Abstract*—In this research image based Fast Feedback (FF) systems are presented, that use image processing and computer vision techniques. The goal of this work is to provide tools for automatic checking and grading of multiple choice questions in quizzes and exams for academic evaluation of students. These tools can be also used to monitor the level of students' understanding of the material and to receive feedback from them about the quality of the lessons during courses in academic institutions. First possible FF setups and processing methods for multiple choice questions are discussed. Then results of experiments with this type of questions are presented.**

***Index Terms*—automatic tools for academic evaluation, fast feedback systems, image based, image processing, pattern recognition**

I. Introduction

In this work we discuss practical implementations of fast feedback systems for automatic checking and grading of answer sheets designed for Multiple Choice (MC) questions. Our goal is to create image based systems that can grade quizzes and exams with minimal involvement of the lecturer. The FF systems are not to be confused with Instant Feedback (IF) systems [1]-[3]. In IF systems, the goal is to determine the answers to a single question of all the students in the classroom, that choose to answer it, at the same time. These systems can be used as one of the methods of Active Learning [4], [5] where it is best when the student feedback is processed instantly.

A number of IF implementations are known, for example, based on wired keyboards or infrared (IR) clickers, which are used in a number of universities [6], [7]. Another IF implementation uses Short Message Service (SMS) communication to collect instant responses of the students [1], [8]. Similarly, Internet based smartphones, tablets or personal computers can be used for the same purpose. Camera based implementations of IF systems have also been used in academic institutions. The interested reader is referred to [2] and [3].

In FF systems, each student feedback is processed separately and does not have to be instant. A reasonable setup is that the student fills an answer sheet for an exam evaluating his or her level of knowledge either during or at the end of an academic course. Such exams can be subject specific or comprehensive, voluntary or mandatory, according to the decision of the lecturer. Our goal here is to present fast methods for processing and grading of such answer sheets. In the next section we discuss methods for the acquisition of the student answer sheets. Then in Section III we present several possible answer sheet designs and in Section IV we discuss methods for their processing. Results are provided in Section V and conclusions in Section IV.

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II. Acquisition of Answer Sheet Images

In a typical FF system, answer sheets are collected by the lecturer in the end of the FF exam and are scanned by using an available scanner. The setup of a scanner based system is obvious.

Another option is to use a digital camera or a smartphone camera instead of scanners. Fig. 1 presents a simple arrangement containing a stand for the acquisition of the answer sheet images using a smartphone. The idea is that each time a student places his answer sheet into a collection box, the camera of the smartphone is used to grab the image. The process is repeated for all the students. Our measurements reveal that the typical time period needed to collect and acquire the images of 45 answer sheets is less than 3 min. In classes with low student motivation to cooperate, answer sheets can be collected and photographed by the lecturer, as in the case of a scanner based FF system.

It is obvious that the scanner can produce images that are significantly easier to process than a smartphone's camera. The camera advantages are faster acquisition of the answer sheets, especially at high resolution, and the fact that the acquisition can be easily done in the classroom without the need for any special equipment except a smartphone and optional stands for it and for the collection box.

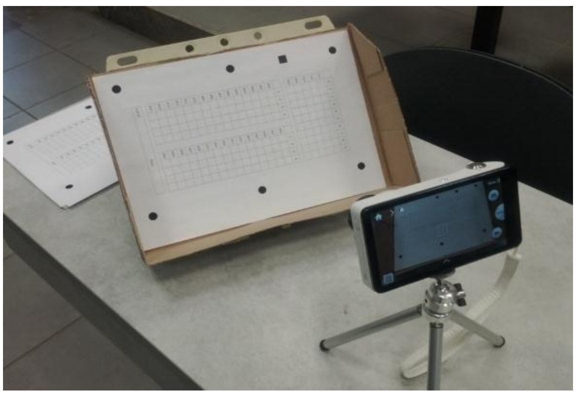

Figure 1. The setup for fast acquisition of answer sheet images.

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III. Answer Sheet Designs

An important issue when designing an answer sheet, that has to be processed in image form, is the choice of markers used to align and scale the image. Marker options are discussed in the next subsection.

A. Choice of Markers

A simple choice for markers can be a rectangular frame as shown in Fig. 2. The frame lines can be detected, for instance, by the Hough transform [9]. The benefit of this option is simplicity, but the drawback of using simple straight lines is that their accurate detection requires relatively high image resolution. In our experiments, rectangular frame detection in scanned answer sheets at 200 dots per inch (dpi) was not always successful. Increasing the scanner resolution to 250 or 300 dpi improved the success rate of frame detection, but lowered the scanning speed for two different scanner models tested.

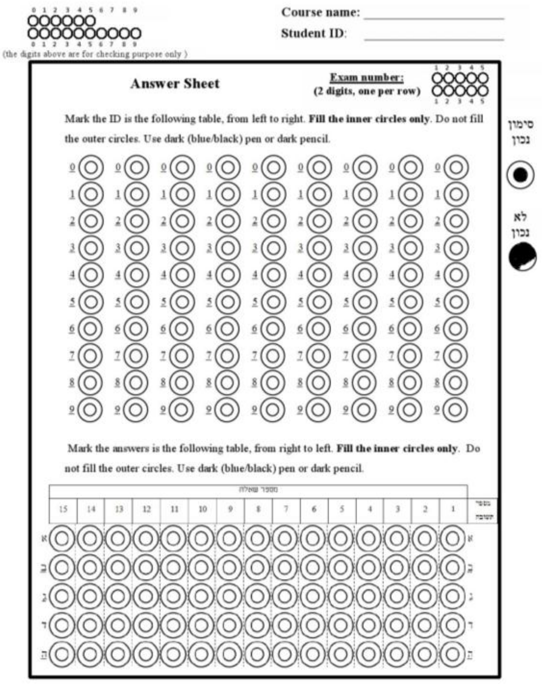

Figure 2. An answer sheet using a rectangular frame as the main marker for aligning and scaling the image after acquisition. Some of the optional information fields in the sheet can be placed outside of the frame.

Another option for markers it to place specific shapes like rectangles, triangles, circles or more complicated forms at the corners of a (possibly imaginary) frame bounding the important information in the answer sheet. Since we assume that the sheets will be acquired by scanners or cameras in a somewhat distorted and rotated form, circles seem to be the most reasonable choice. Using circles, as demonstrated in Fig. 3, allows large rotation angles without the need to change the marker recognition algorithm since these markers remain circular even if the image is rotated at any angle and distorted to a small extent in the acquisition process. Another advantage is the existence of simple methods to detect circles in images (See Section IV, Subsection A). The drawback of using circular markers is that they can be confused for the circular checkboxes that can be used for filling in the answers, as will be discussed in the next subsection. To make the markers easily distinguishable, we suggest either using a bigger radius or making them more complex (Fig. 3). Then, however, one can argue that the design may be not as aesthetical as with rectangular frame markers.

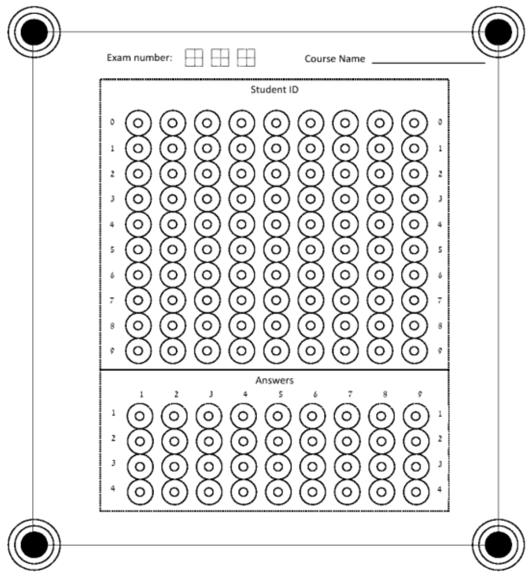

Figure 3. An answer sheet using 4 circles as corner markers for aligning and scaling the image after acquisition. Optional rectangular frames can be included as well to improve the design clarity.

While four corner markers are adequate for the scanner based FF system, in the case of image acquisition using a digital camera more markers may be needed because of additional geometrical distortions. Fig. 4 presents an answer sheet design containing seven markers enabling us to compensate for those geometrical distortions. When a camera is used to acquire the answers sheet images in a fast way, correct orientation of the answer sheet is not guaranteed. A rectangular marker, positioned in this design in a non-symmetrical way, enables determination of the correct orientation of the answer sheet.

Yet another option to be considered is the use of color markers, for example, similar to the markers used in the camera based IF systems [2]. We have not used color markers in this work due to technical limitations of mass printing and scanning in color.

B. Multiple Choice (MC) Questions

The typical design for answers to multiple choice questions is using rectangular checkboxes (Fig. 5) or circular ones (Fig. 2 and Fig. 3). Such checkboxes can be used both for marking the student ID with one column of 10 boxes for each digit and for the answers themselves with typically one column of 4-5 boxes per question, each one used for a different number of the answer.

When using circular checkboxes, we found it beneficial to use two circles, one inside the other, where the student marks the inner circle by coloring it and the outer circle is used for detecting the circular checkbox locations. Our goal was to design checkboxes that allowed self-correction, meaning that when processing each column of ID or answer boxes, the algorithm could correct itself based on the detected locations of the checkboxes compared to the assumed one (see Section IV for details).

Another option instead of checkboxes is to use rectangular boxes in which the student can mark his selection by using any symbol or shape written by a dark pen, as long as the size of the darkened area of the box exceeds a certain pre-defined limit. Examples for this can be seen in Fig. 4.

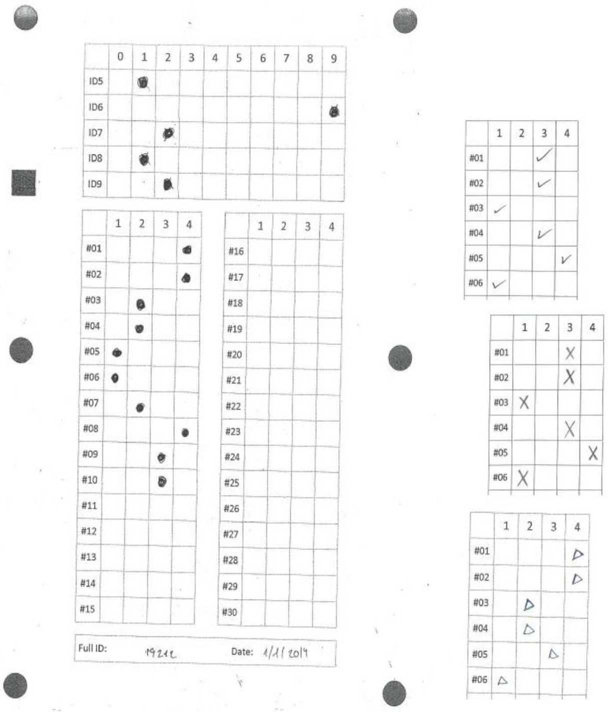

Figure 4. An answer sheet using 6 circles and 1 rectangle as markers for aligning and scaling the image after acquisition. In this design the student can mark his selection by using a black pen to draw any symbol, as long as the "black area" inside a specific rectangular box exceeds a predefined limit.

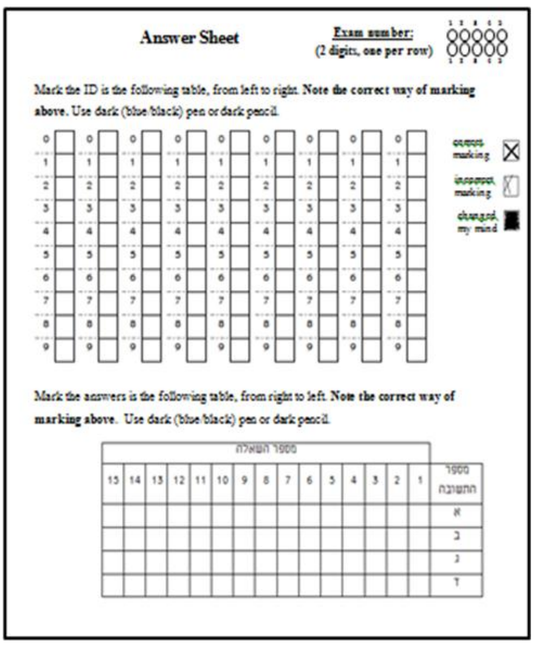

Figure 5. An answer sheet with rectangular answer boxes

Practically, the number of questions and possible answers may be small. Additionally, a short ID is adequate in many situations, for example, the last 5 digits of the full student ID. In this case, the size of the answer sheet can be very compact, as in Fig. 6. The advantage of this design is that a camera with lower resolution can be used or, alternatively, a high resolution camera can be used to photograph several answer sheets simultaneously.

Note that there are also additional optional fields in the answer sheet designs of Fig. 1-Fig. 6, such as the course name, the exam date and the student ID for filling in by writing as well as the exam version number for marking using checkboxes. Another field, seen in Fig. 2 above the rectangular frame on the left, is for marking the grade of the other parts of the exam for the checkers' use. This is convenient when the exam has multiple parts, e.g., one with MC questions and one with regular "open" questions. After grading the latter part of the exam manually, the checker can mark its grade on the answer sheet and check the multiple-choice part automatically. The final grades will then be calculated in addition to the MC grades.

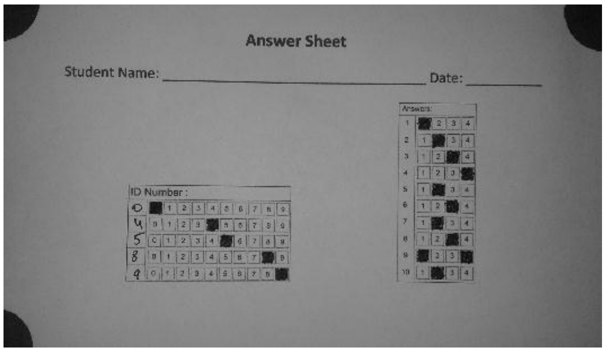

Figure 6. A small-size answer sheet with 10 MC questions, using 3 corner circular markers (partial circles) for image alignment.

IV. Processing Methods

First we discuss the marker recognition process.

A. Marker Recognition Methods

For the purpose of detecting a rectangular frame, the quickest method in our experiments turned to be the Hough transform for detecting lines [9]. The frame was detected by extracting the longest vertical and horizontal lines closest to the sheet boundaries. As mentioned before, there were problems of misdetection when the image resolution was not high enough, for instance, when the image acquisition device was a scanner with 200 dpi resolution.

When circular markers are used, one can employ such methods as the circular Hough transform [10], [11] and normalized correlation [12]. The first method has the advantage of speed, but is less accurate than the second technique. We thus recommend using the normalized correlation to detect the markers.

B. Image Aligning and Calibration

Once the markers have been located, the image can be rotated to a vertical orientation and scaled to a predefined size. We use a process of calibration for faster reading.

As part of this method, the first image we process is an empty answer sheet (referred to as the nominal image),

where the user marks the positions and sizes of the ID checkboxes, the answer boxes, etc., in the way demonstrated in Fig. 7. These nominal positions and sizes are stored and used for the processing of all the following images. For each image, once it is aligned, scaled and the bounding frame of the answer sheet is detected, the nominal positions and sizes are used to calculate the assumed ID and answer checkbox locations using, for example, the following formulas:

$$ZoomFact = 0.5 \cdot \left(\frac{DetFrameWidth}{NomFrameWidth} + \frac{DetFrameHeight}{NomFrameHeight} \right) \quad (1)$$

and

$$\begin{aligned} BoxLeft &= \left[DetFrameLeft + ZoomFact \cdot \right. \\ &\quad \left. \cdot \left(NomBoxLeft - NomFrameLeft \right) \right] \\ BoxTop &= \left[DetFrameTop + ZoomFact \cdot \right. \\ &\quad \left. \cdot \left(NomBoxTop - NomFrameTop \right) \right] \end{aligned} \quad (2)$$

Here $ZoomFact$ is the scaling factor, $DetFrameWidth$ and $DetFrameHeight$ stand for the detected size parameters of the bounding frame, while $NomFrameWidth$ and $NomFrameHeight$ stand for the nominal size parameters of the bounding frame. Also, $DetFrameLeft$ and $DetFrameTop$ denote the location of the top left corner of the detected frame and, similarly, $NomFrameLeft$, $NomFrameTop$ of the nominal frame. Finally, $BoxLeft$, $BoxTop$ stand for the location of the top left corner of a certain rectangular box or for the center of a circular box in the processed image. The same parameters with the *Nom* prefix denote the location of the box in the nominal image. This can be an ID or answer checkbox. The size of the box is adjusted as well by multiplying its nominal size parameters (width and height or inner and outer radii) by the zoom factor of (1) and rounding the results.

We do not rely on these calculations to be highly accurate and thus our algorithms are self-corrective as discussed in the next subsection.

C. Reading the MC Checkboxes

In our experiments the rectangular checkboxes were read using the line Hough transform, while the circular ones were read using the circular Hough transform to detect the outer circles. Once the ID/answer checkbox was located, the intensity of the pixels inside it was compared to a threshold and the percentage of pixels below the threshold was counted. If this percentage was above, for example, 50%, then the box was considered as marked. Otherwise it was considered unmarked. All the checkboxes in each ID/answer column were tested, so that multiple marking or no marking at all could be easily detected.

For both types of checkboxes, we used the self-correction process, mentioned earlier, in which when reading a column based on the assumed locations and sizes, calculated as in (1) and (2), the real locations and sizes of the checkboxes were detected. Then the algorithm could correct itself before proceeding to the next column. This way the calibration errors were not accumulating from one column to the next.

When comparing the two types of checkboxes, we discovered that circular checkboxes allowed higher accuracy and better robustness to errors in the marking of answers than rectangular checkboxes.

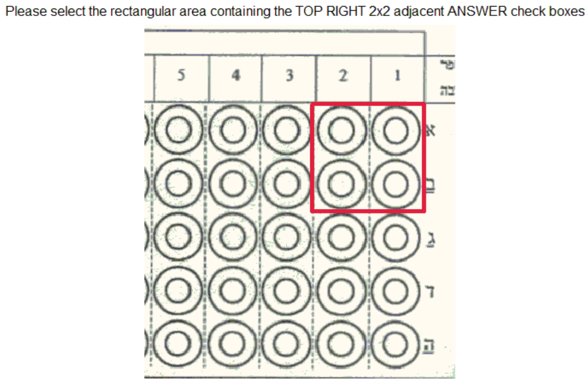

Figure 7. The user marks four answer boxes as part of the calibration process. The starting position and size of the answer boxes are extracted and stored.

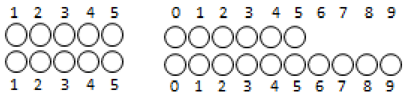

Figure 8. Exam number checkboxes (left) and input grade checkboxes (right).

D. Reading the Additional Fields in the Answer Sheet

Two optional fields in our answer sheet designs, as mentioned in the end of Section III, are the exam version number and the grade of the other parts in multi-part exams. This grade is marked by the checkers in the answer sheets and later read along with the student ID and answers. We denote this grade by “input grade”. For simplicity, we designed the checkboxes for these fields as simple circles, as shown in Fig. 8. These circles were read by the normalized correlation method using the digits above them for the correlation calculations. While the circles change in appearance once filled, the digits do not.

V. RESULTS

A. Experiments in MATLAB Environment

We conducted experiments with MC designs acquired by both scanners and cameras and processed by our algorithms in MATLAB environment. Fig. 9 shows an example of a multiple choice answer sheet processed by our program. Note that only 5 digits of the student ID were used in this experiment to recognize the examinees. The information detected in this answer sheet is summarized in Table I. Our MATLAB program was able to read all the answer sheets in several exams and produce final grade tables, such as the one shown in Table II. Here not only the student IDs (5 digits) are given the leftmost column and the final grades are given in the rightmost column, but also the other columns, titled Q1-Q11, show whether each student answered the eleven

MC questions of the exam correctly (value of 1) or not (value of 0).

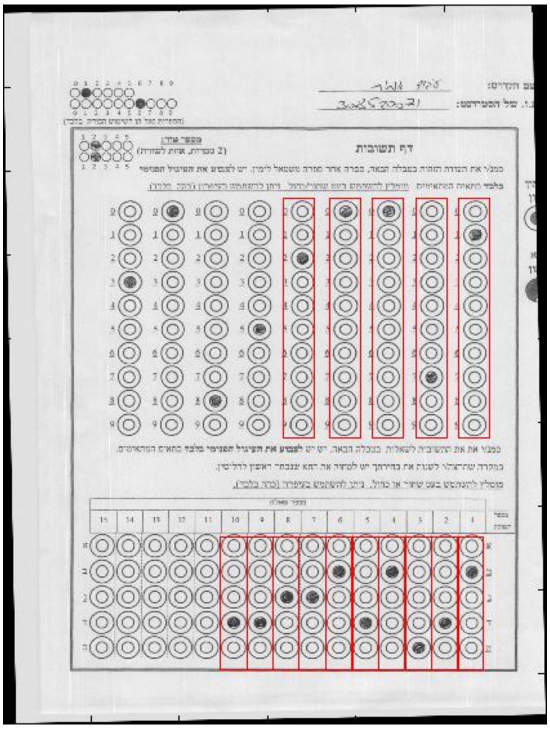

Figure 9. An MC answer sheet being processed by our algorithm. Each ID/answer column being read is marked for monitoring.

TABLE I. ID AND ANSWERS READ FROM THE ANSWER SHEET IN FIG. 9

Student ID (5 digits)	95750
Student answers (Q1 right to Q11 left)	5 4 3 2 4 2 3 4 1 3 2

Overall, the accuracy of reading the MC answer sheets was above 97%. The processing program would stop at any ID or answer column with no or multiple marking and wait for the user's help. Also, in some rare occasions the user's intervention was needed due to incorrect marking of the checkboxes, such as when using a bright pencil or pen.

In addition to the results above, a full-scale Android Application was developed for the small-size answer sheets presented in Fig. 6. We describe this application next.

B. Dedicated Android Application

The main screen of our Android application is shown in Fig. 10 on the left. As can be seen, the application can be used both for acquiring the images and for processing them, producing the finals scores or grades. The right side of Fig. 10 presents a convenient screen used to input the correct answers for a specific exam. These answers are to be used in order to calculate the student grades.

Fig. 11 presents an intermediate result of the Android application, where the ID and answer areas were recognized. Following this stage, the extraction of the ID and the marked answers was based on the methods in Section IV, Subsection C. The current implementation of the Android application suffers from low image processing speed in inexpensive smartphones. A simple solution is to grab the images using the smartphone's camera and then send the acquired pictures to a cloud server running MATLAB image processing utility. Our preliminary results show that this method may be preferable when an internet connection is available after the end of the exam.

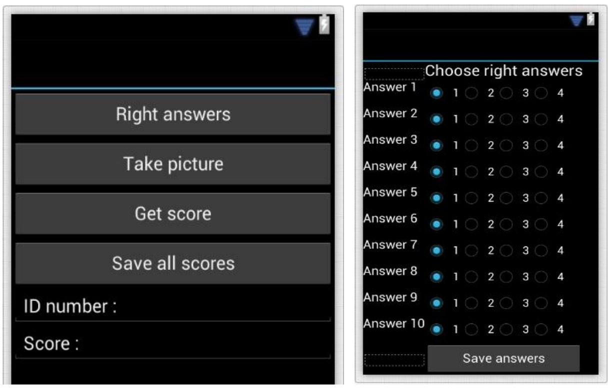

Figure 10. Left: main screen of the android application designed for the answer sheet acquisition and processing.
Right: screen of the android application designed to input correct answers to be used in the student grade calculation.

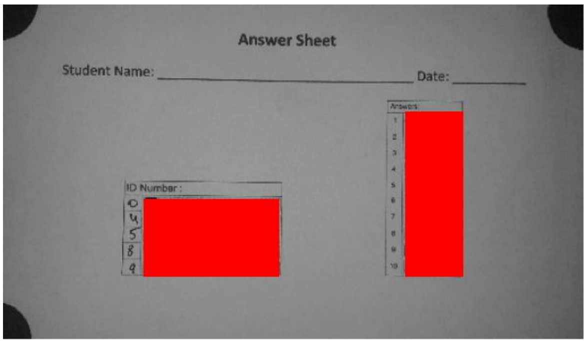

Figure 11. An intermediate result of the android application, showing the ID and answer areas recognized correctly (in red).

VI. SUMMARY AND CONCLUSIONS

Our work is focused on image based Fast Feedback systems for automatic checking and grading of quizzes and exams in academic institutions. We have presented several designs for including multiple choice questions in the exams and discussed the advantages and drawbacks of the different options. We have implemented the designs in real life examinations and achieved good results both on a PC and on an Android platform. Our conclusion is that the presented designs and processing methods may be very beneficial for automatic evaluation of students in academic institutions.

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TABLE II. GRADE TABLE EXAMPLE. THE COLUMNS INCLUDE THE STUDENT ID (LEFTMOST), THE FINAL GRADE (RIGHTMOST) AND WHETHER THE STUDENT REPLIED CORRECTLY TO EACH OF THE 11 QUESTIONS IN THE EXAM: 1 DENOTES A CORRECT ANSWER AND 0 DENOTES A MISTAKE.

ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Grade
19174	0	0	1	1	0	1	0	0	0	1	1	45
08644	1	0	0	0	1	1	1	1	0	0	1	55
19212	0	0	1	0	0	1	0	1	0	1	1	45
74097	0	1	1	0	0	0	0	0	1	0	1	36
14569	1	1	1	1	1	1	1	1	1	0	0	82
83670	1	1	1	1	0	1	1	1	1	1	0	82
17839	0	0	1	1	1	1	0	1	0	1	1	64
47530	0	0	1	1	0	1	0	1	1	0	0	45
94094	1	1	1	1	1	1	1	1	1	0	0	82

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