

Feasibility of a Camera-Based Instant Feedback System

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Abstract—The Instant Feedback System (IFS) described in this article is designed to collect students' responses to a series of multiple-choice questions. An IFS enables the educators to improve their teaching by generating real-time feedback from the students about the clarity of the lesson. A number of IFS are known: systems using wired mini-keyboards, infrared clickers, SMS or Internet-based smartphones applications, etc. Our long-term goal is to create an IFS system based on the use of digital camera. In the frames of camera-based IFS implementation, every student attending the class receives a specially designed card containing a predefined number of color markers and a 2D barcode. When the students are asked a multiple-choice question, they answer by physically raising their cards. The 2D barcode on the card is used to encode the student's ID, whereas 2D orientation of the card encodes the number of student's answer. A number of images of the class are grabbed by the IFS camera and processed by a computer, which generates a list of student grades. Reliability of the chosen card design and camera placements is analyzed. We conclude that the chosen card recognition process demonstrates feasibility of the camera-based IFS approach.

Keywords—*image processing; 2D barcode; color recognition; OCR; IFS*

I. INTRODUCTION

Instant Feedback System (IFS) is a tool for real-time acquisition and processing of human responses. IFS described in this article is designed to collect student responses to multiple-choice questions in the frame of "active learning" approach. A number of researchers claim that active learning as a concept and IFS as a tool for active learning enable the educators to improve their teaching by generating real-time instant feedback from the students about how clear a specific lesson is for a specific student [1, 2]. A number of IFS implementations are known and every one of these has its own advantages and drawbacks. One of the implementations uses wired keyboards, which are simple and reliable, but wiring requires special rearrangements in the class in accordance with safety rules and this is not always possible. Another implementation uses infrared (IR) clickers, which are used successfully in a number of universities [3, 4, 5]. However, price of the clicker and data collector(s), physical size of the clickers, and the need for periodic battery replacements makes wide usage of IR clickers problematic in low-budget universities and colleges. Another IFS implementation uses Short Message Service (SMS), Internet based smartphones, tablet or PC-based applications to collect instant responses of the students [6, 7]. Simplicity of implementation and logistic

advantages of the smartphone-based IFS are obvious to anybody skilled in the art, however, in some classes the use of mobile devices is forbidden (at least during exams). The motivation of this research is to design, implement and test a simple and inexpensive IFS. Considering low prices of modern high-resolution digital cameras, we decided to check the feasibility of a camera based IFS.

The structure of the article is as follows. In the Section II, we present elements of the camera-based IFS, its design and operation. IFS card design is described in the Subsection A. Image acquisition is described in Subsection B, and images handling in Subsection C. Then, in Section III, we describe main elements of the IFS Card recognition software. Section IV is dedicated to results of the camera-based IFS usage in the class. Section V presents a summary of this work, conclusions and possible ways to improve reliability of the camera-based IFS.

II. IFS ELEMENTS, DESIGN AND OPERATION

In the frames of the chosen approach, each student in the class gets one IFS card at the beginning of the semester or at the beginning of the lesson. It is assumed that the class is equipped with a lecturer' computer with a projector (as seen in Fig. 1). It is additionally assumed, that lecturer can operate high-resolution digital camera. During the lecture at one or more times, the lecturer presents to the students a slide containing a multiple-choice question (later referred as IFS exam). After a certain time interval (e.g., 30 seconds) the lecturer asks the students to present their answers by raising their cards. The card design is presented in Fig. 2 and is described in details below. The digital camera grabs a sequence of images of the class and stores those images. Specially designed software processes those images and generates grades list. During November 2012 – January 2013 10 IFS exams were provided in the small-size class of 16 students in the frames of Image Processing Laboratory (later "ImProc") and 10 IFS exams were provided in the auditory designed for up to 60 students in the frames of TAE course. Fig. 1 presents an exemplary image of the class during ImProc IFS exam. Fig. 3 presents two images of the class during TAE IFS exam. Each student in the class is invited to raise his individual card as an answer to the multiple-choice question asked by the lecturer during the lesson. Callouts of different colors presents results of IFS exam (in the format "Short ID of the Student" / "Number of the Answer"). Relevant technical details follow.

A. IFS Card Design

Our IFS card is of size 20cm x 20cm and contains three markers, which are 4cm x 4cm squares having Yellow, Magenta and Cyan colors, and a number of black circles (see Fig. 2). The black circle diameter is 2.5 cm and up to six black circles can be positioned in predefined places on the card. These six positions for black circles correspond to 6 bits of a custom 2D barcode and enable encoding integer numbers from 0 to 63 as specified in Fig. 2. This 6-bits number is used to encode student number in the “class list”, and is referred later as Short ID (SID). In the current implementation, the number of answers in the multiple-choice questions is four, which can be considered adequate for most questions of this kind. The number of the answer chosen by the student (#1, #2, #3 or #4) is encoded using the 2D orientation of the card relative to the horizon line. For example, positioning the IFS card so that the “Magenta” rectangle is in the right-bottom corner (as seen by the IFS camera) encodes answer #1, positioning the card so that the “Magenta” rectangle in the left-bottom corner encodes answer #2, etc. Additional “Yellow” and “Cyan” rectangles enable reliable evaluation of the card orientation. It should be noted that the back side of the IFS card contains small-size numbers (1, 2, 3 and 4) positioned at the corners of the card, so that the student orients the card in such a way that the selected answer number (seen by the student) is in the uppermost position (as shown in Fig. 2). IFS Cards are printed on the thick white paper by using specially designed “Printing Utility” (see Fig. 4 left) and folded for the proper rigidity (as shown in Fig. 4 right).

B. Image Acquisition

In a small class, one wide angle camera can monitor all the students (as seen in the Fig. 1). However, in most classes even a wide-angle camera cannot cover all the relevant areas of the class. Obvious solution is to make a number of shoots by properly rotating and translating the camera as presented in the Fig. 3: minimum two images of the TAE class were required. Practically, a bigger number of images – typically 3-5 images were collected for every IFS exam. For the internal software tests 5MP Logitech c920 HD Pro Webcam connected to PC was used. Logitech camera was positioned on the rotating stage. Specially designed PC software can control camera rotation and camera parameters for every camera position, so that for every specific class optimal image acquisition sequence can be created, tested and stored [8]. However, at the beginning of the semester, this IFS prototype was not operational. Hence, in this research, all the images were collected by using from-the-shelf digital cameras. Cameras were operated in the simplest “auto” mode without tripod. For example, image presented in Fig. 1 was collected by using a simple digital camera (Canon IXUS 200HS, Image dimensions: 4000 x 3000). Images presented in Fig. 2 were collected by using Samsung Galaxy EK-GC100 Android-4 camera/PDA (Image Dimensions 4608 x 2592).

C. Image Handling

Practical Instant Feedback Systems must process raw images stored in the camera memory and present results instantly. In this work, raw images were stored in the camera’s flash memory and later copied to the computer as JPG files for the processing. This approach enables to compare different cameras and evaluate if the resolution and image stabilization of the specific camera are adequate. Additionally, intermediate storage of all the images as files enables post-processing of the same image using different algorithms. It must be noted, that from-the-shelf digital camera does not provide access to raw image data. Hence, compressed JPG images were manually “decompressed” to BMP images. In case of the Canon camera, typical decompressed BMP image size was 34.3 MB. For the Samsung camera, decompressed BMP image size was 34.1 MB.

III. RECOGNITION SOFTWARE

A. Color Markers Detector

A number of well-known approaches used to detect shapes of different colors were evaluated [9-13]. Additionally, certain elements of the approaches and algorithms described in [14, 15] were used.

Images collected during IFS exams were processed by using specially designed “Image Recognition Utility”. Taking into account that colors of the simple printer used to print the IFS cards are not pure “MCY”, taking into account illumination differences and differences in the color characteristics of the different cameras, practical values of the “MCY” colors were evaluated from the typical images.

In order to find color markers two algorithms were used. Algorithm #1 was based on “Color Blobs” concept [11, 12]. Algorithm #2 was based on “Pixel Labeling” approach [13].

For most images, both algorithms provided the same results. Fig. 5 presents an example of color marker recognition by using Algorithm #1. It can be seen that all the markers of all the IFS cards are successively recognized as rectangles. Additionally, it can be seen (by manual inspection of images in Fig. 1 and Fig. 5) that marker centers are recognized with nearly pixel accuracy. It can be seen that the Magenta color was detected in other places, e.g., the students’ faces and bare areas of their hands. Considering the way the cards were designed, this was not a problem for the images analyzed. However, we plan to provide some card design modifications in the future.

After center of the color markers evaluation, process of “Cards Bounding” was executed. Referring to Fig. 6, first available “magenta center” was set as Point “M” and closest Point “C” and Point “Y” were looked for. Then distances “Y-M” and “M-C” in pixels between above points were evaluated. In case above distances were in the predefined limits, angles “YMC”, “MCY” and “CYM” were calculated and compared with predefined limits. In case angles “YCM” and “CYM” were close to 45°, angle “CMY” was close to

90°, then card was considered as “found” and its bounds were considered as known. This process was repeated for all magenta centers and results in the cards bounding (see Fig. 6 right). On this stage card orientation (encoding number of the answer in accordance with Fig. 2) was evaluated by calculating angle between “C-M”/“M-Y” and horizontal line.

B. 2D Barcode Analyzer

By using the row and column, coordinates of the marker centers image registration for the specific card can be easily executed. Considering that the surface of the card is white and the SIDs are encoded using black circles of predefined sizes and positioned at predefined places (as presented in Fig. 2), SID extraction is trivial. Combining SID and the chosen answer number, a final list in the format “student’s ID, student’s answer, grade” is compiled and presented to the lecturer for the purpose of student achievement analysis. Results of two exemplary IFS exams are presented in Fig. 7.

IV. RESULTS

Comparing color callouts presented in Fig. 1 and Fig. 3 and tables presented in Fig. 7, it can be seen that while IFS card is properly presented to the camera, recognition of multiple cards is reliable enough even for the current card design and current image processing tools. It is obvious that overlapping cards ruin algorithms used. In order to prevent this, students were asked to use simple optical rule: “If you can see the camera – then the camera can see your card”. Senior students attending Image Processing Laboratory were cooperative enough and motivated enough to voluntarily participate in IFS exams and follow obvious exams rules, so that recognition rate in this small group was above 90%. As seen in the Fig. 1, only one card near the window was not recognized. Students of the TAE course were less cooperative. It can be seen that only 30 students of 40 enrolled were present during exam #6 (presence in the lecture is not obligatory). Five students effectively not participated in the exam: by raising cards in the obviously wrong way or by non-raising cards in the due time (Blue callout). In three cases “Image Recognition Utility” failed to recognize cards (Red callout). It can be seen that all those three cards were raised in the last row. Post-exam tests reveals that diameter of the block circles for the problematic cards is about seven pixels only.

V. CONCLUSIONS AND FUTURE WORKS

The proposed camera-based IFS design and the selected image processing algorithms prove feasibility of the camera-based IFS approach. The proposed IFS is extremely inexpensive, simple to implement and requires minimum deployment efforts, thus it can be beneficially used to improve learning and teaching in institutes of education, such as schools, colleges and universities. In the future, we plan to implement fully automated real-time image acquisition and

data processing. We expect that using automated image acquisition system utilizing computer controlled camera rotation and computer controlled brightness, contrast and zoom, will improve IFS reliability. Additionally, we plan to implement, test and compare a number of different machine and human oriented IFS cards designs. We plan to use color edges in the future IFS cards design and to use robust color edge detectors [14, 15] to improve practical reliability of the camera-based IFS.

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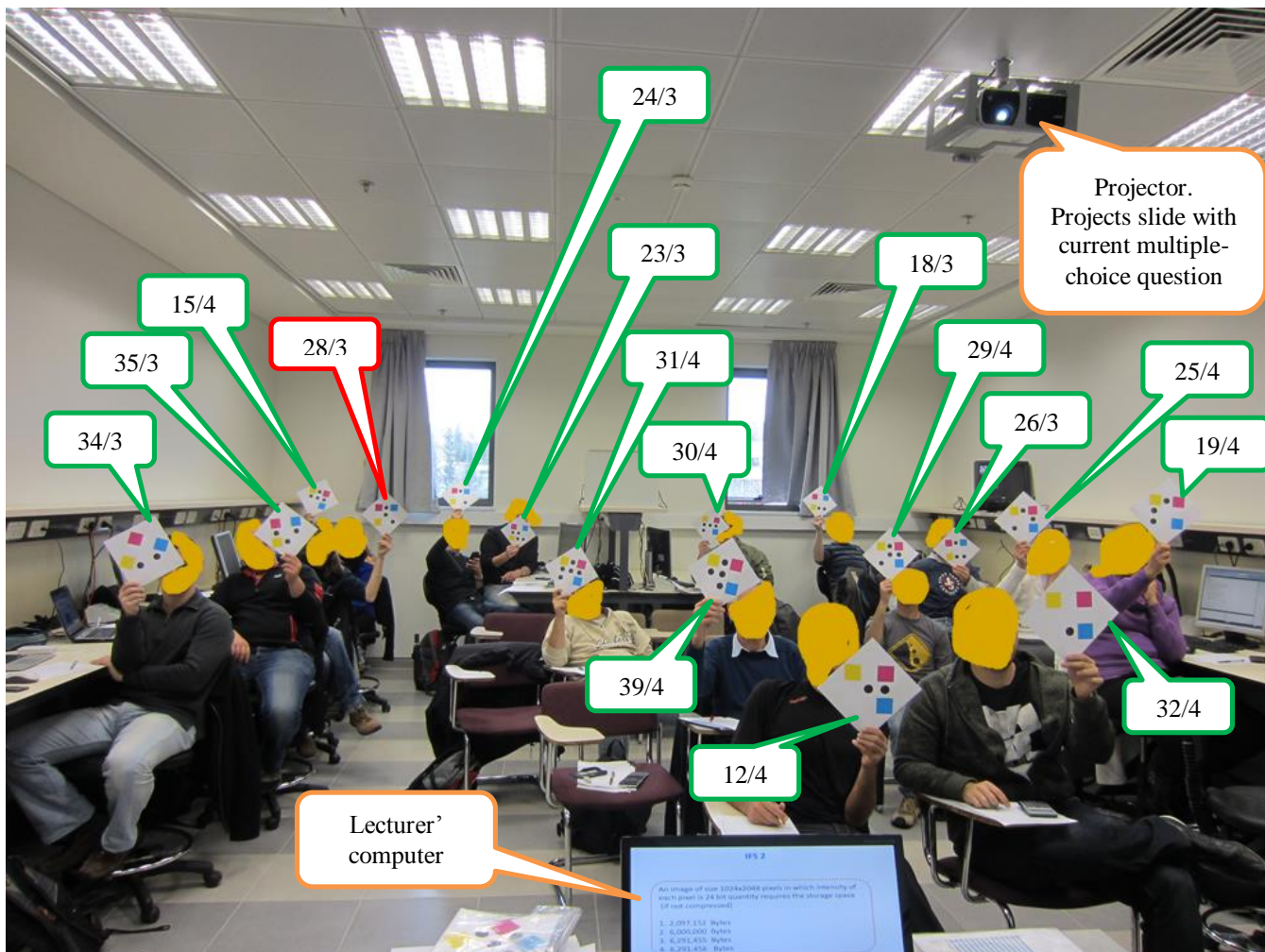


Figure 1. An exemplary multiple-choice ImProc IFS exam #2. See the text and following figures for detailed explanations. The faces of the students participating in the exam were manually brushed.

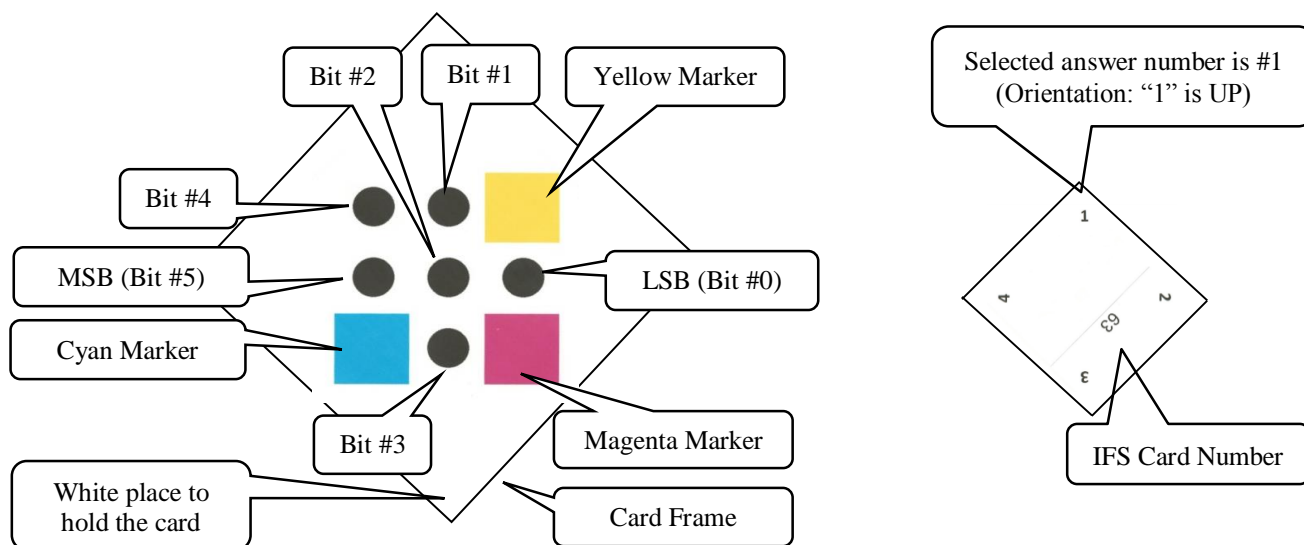


Figure 2. Left: Front side of an IFS card #63 as seen by the IFS camera (Selected answer number is #1). Right: Back side of an IFS card #63 as seen by the student.

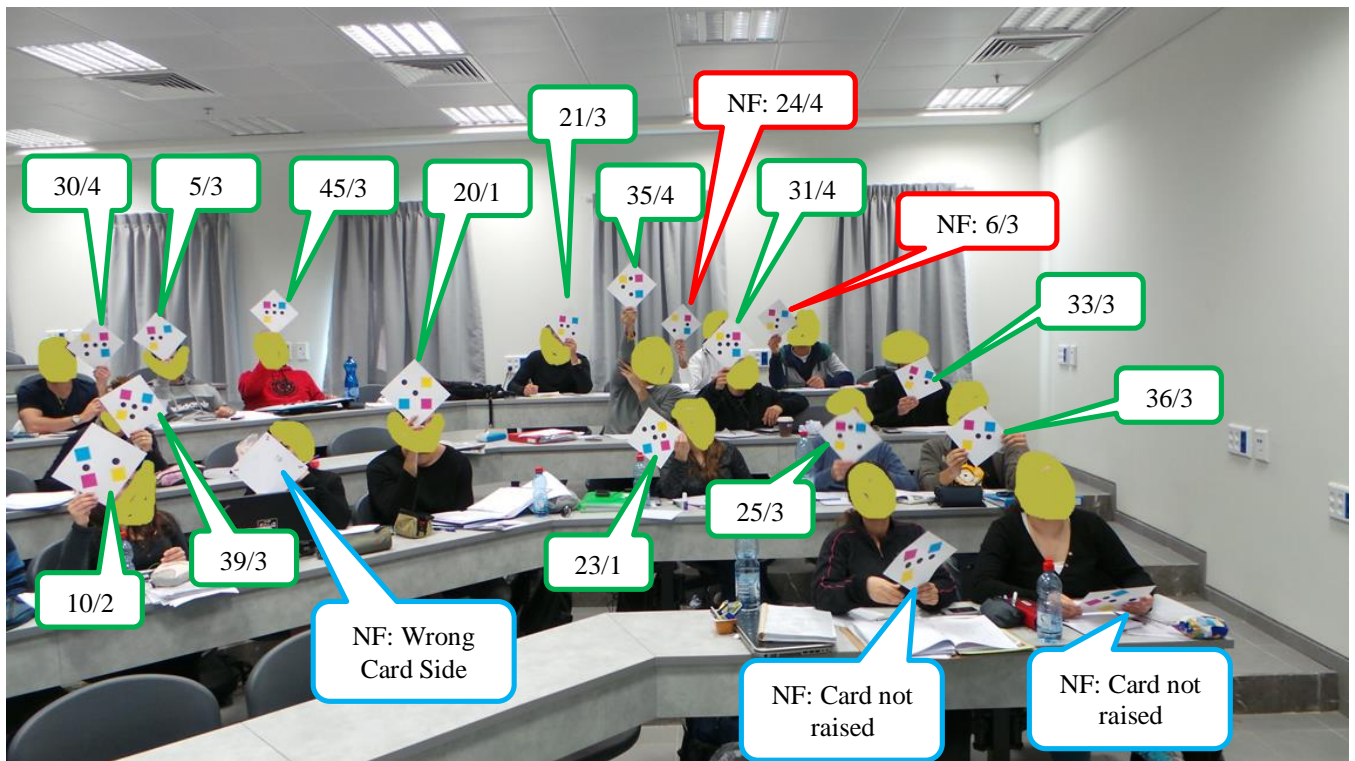
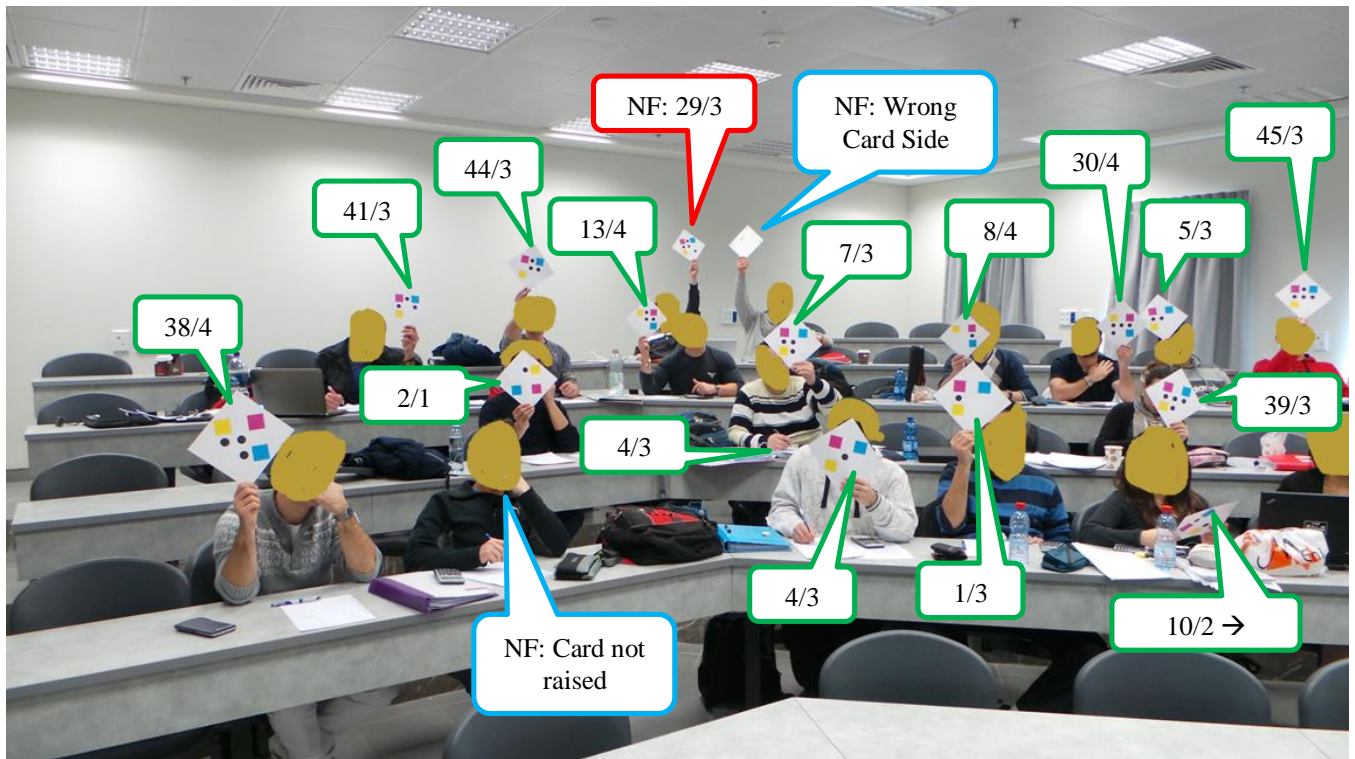


Figure 3. An exemplary multiple-choice TAE IFS exam #6. Minimum two images required to cover the class. See the text and following figures for detailed explanations. The faces of the students participating in the exam were manually brushed.

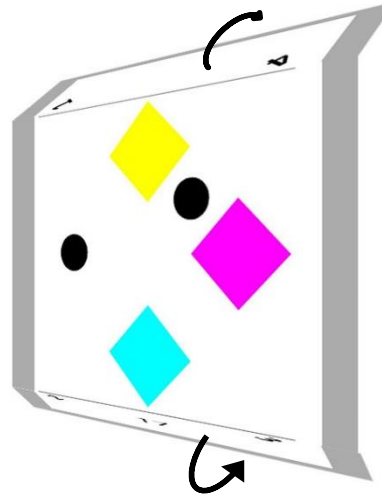
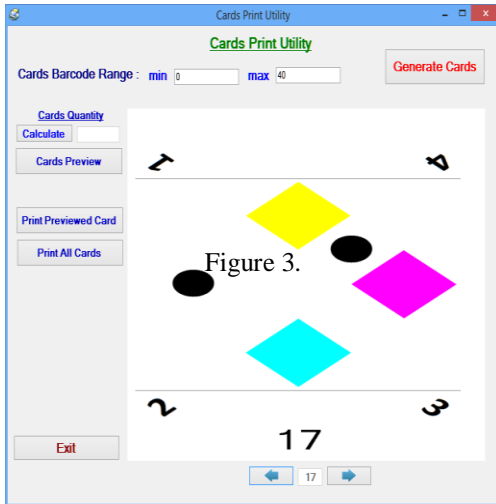


Figure 4. Left: GUI of the IFS Card Printing Utility. Right: Folding IFS card to create “front” and “back” sides as shown in Fig. 2.



Figure 5. An example of color markers recognition. All the markers of all 16 IFS cards (see Fig. 1) were successfully recognized as color rectangles. The calculated geometrical centers of the rectangles are marked as black dots.

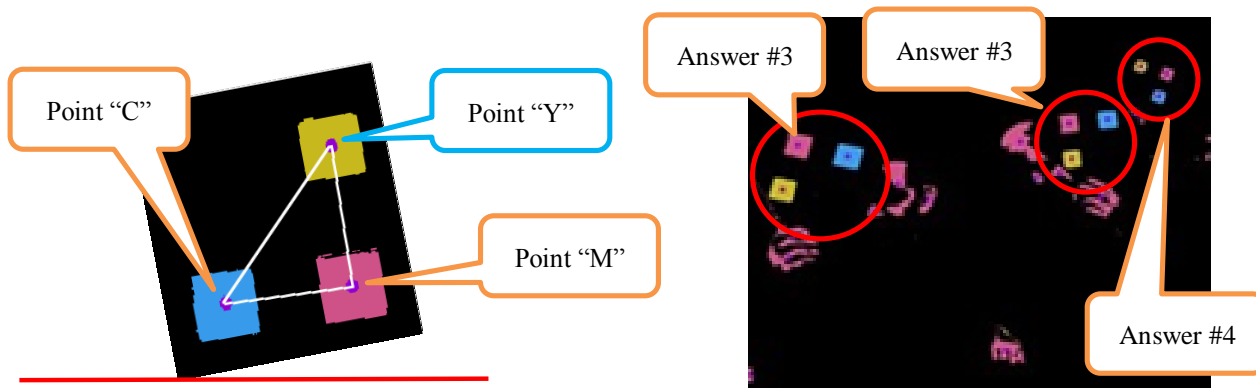
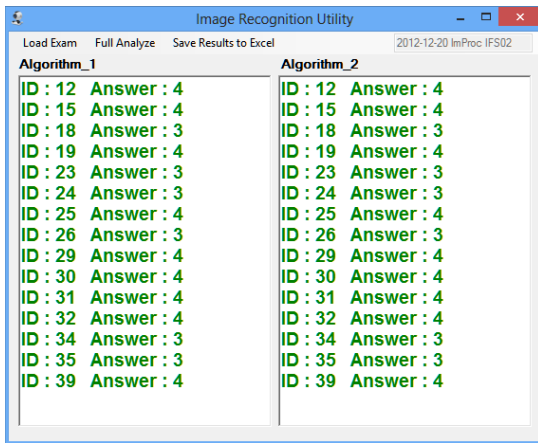


Figure 6. Left: Important angles between Color Markers and horizontal line. Right: Exemplary bounding of the three leftmost cards (from the Fig. 5) by distances and angles between markers. Number of the answer is evaluated by the found card orientation.



	A	B	C	D	E
1	2012-01-21 TAE3				
2	Algorithm1		Algorithm2		
3	*****		*****		
4	ID	Answer	ID	Answer	
5	1	3	1	3	
6	2	1	2	1	
7	4	3	4	3	
8	5	3	5	3	
9	7	3	7	3	
10	8	4	8	4	
11	10	2	10	2	
12	13	4	13	4	
13	20	1	20	1	
14	21	3	21	3	
15	23	1	23	1	
16	25	3	25	3	
17	30	4	30	4	
18	31	4	31	4	
19	33	3	33	3	
20	35	4	35	4	
21	36	3	36	3	
22	38	4	38	4	
23	39	3	39	3	
24	41	3	41	3	
25	44	3	44	3	
26	45	3	45	3	
27					

Figure 7. Real IFS Exams Results.

Left: GUI of “Image Recognition Utility”. Result of ImProc IFS exam #2.

Image of the class was presented in Fig. 1. Processing time 18 sec.

All 15 presented pairs {ID - number of answer} are correct for both algorithms.

For the card #29 markers were successfully detected, number of the answer was successfully detected; however ID detection was failed (marked by Red callout in Fig. 1) probably because of backlight from the window: central region of the IFS card is more transparent than periphery region (see Fig. 4 right)

Right: Excel table created by “Image Recognition Utility”. Result of TAE IFS exam #6.

Two images of the class were presented in Fig. 3. Processing time 35 sec.

All 22 presented pairs {ID - number of answer} are correct for both algorithms.

Some cards are seen as in the first as in the second images of the Fig. 3.

In this case, last result is logged. For example: card #10 is not raised yet in the first image, but is raised in the second image.

Three images from the last row were not recognized by the “Image Recognition utility”. (Marked by Red callout in Fig. 3)

Probable reason for failed recognition is the lack of camera resolution.