

Automated Capture of Paper-Based Evaluations to Provide Early Feedback to Students

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Abstract—Current Learning Management Systems (LMS) are able to use the data automatically captured from the actions of their users to provide immediate feedback to students and to provide a rich dataset to be mined or analyzed to understand and optimize the learning process. However, in traditional education, not all, or even the majority, of learning products are created or processed through the LMS. Traditional education still uses paper-based assignments and assessments as an integral part of the process. In these cases, the data contained in the LMS is often incomplete and do not provide a holistic view of the students' activities. To alleviate this problem, this work describes SARA, a system to automatically capture paper-based assignments and evaluations while the instructor is writing feedback and grading them. This information is uploaded automatically to the LMS to become part of both, the feedback provided to students and the data available for analyzing the learning process. This system is based on low-cost hardware and requires little configuration and intervention from the final user to work. An initial evaluation of the system provides evidence of the feasibility and usefulness of SARA in real-world learning environments.

Index Terms—Embedded System, computer vision, evaluation feedback, LMS, paper based assessment, fiducial mark.

I. INTRODUCTION

Information and Communication Technologies (ICT) have been used extensively in classrooms with an overall positive impact on the accessibility and quality of education. The emergence of ICT platforms such as Learning Management Systems (LMS) has greatly augmented and enriched the communication between student and teacher. A LMS allows for opportune feedback between student and educators, specially during evaluations, that can be used by students to improve their learning [1]. Simple, automated, and enriched evaluation feedback is one of the strengths of a LMS system and has been demonstrated to improve the quality of learning [2]. Moreover, the new discipline of Learning Analytics makes use of the data produced by LMSs to gain a better understanding of the learning process and to optimize it when possible [3]. The quality of the analysis and the consequent insight gained about the learning process depends on the quality and coverage of the information captured by the LMS.

Learning Management Systems, however, are usually limited to the digital realm and are not as useful when paper-

based activities are used. In these situations, there are different ways to provide feedback ranging from verbal, text, to a personalized video-based form [4]. All of these forms have their limitations making this process not as simple as grading an online submission. Aiming to improve the student-instructor communication during paper based assignments and assessments, we developed an external tool that makes it easy to incorporate these types of work as first-class activities in the LMS. We have called this system SARA (initials for Automated Feedback Capture System in Spanish). SARA is a device still under development capable of scanning paper-based assignments and assessments together with the instructor's written feedback, correct for perspective and camera angle distortions, automatically identify the student and page number, and upload the assignment as a digital submission to the LMS. Once uploaded to the LMS, the student can revise the graded work and the instructor's feedback. Similar solutions focus on improving the grading process, allowing the instructor to provide feedback using digital channels. In contrast, SARA preserves the traditional grading and feedback procedure by silently digitalizing and uploading written feedback while the instructor is grading the paper-based assessments.

This work is structured as follows: Section II provides a review of related work and an explanation about the main differences and contributions of the present work. Section III describes the design decisions made to create SARA. Section IV presents a detailed description of how the main components of the system work and communicate. In section V a small-scale evaluation of the feasibility and performance of the system is conducted, presenting results from its use in a real-world educational scenario at ESPOL university. Finally the work closes with some conclusions (section VI) and future work (section VII).

II. RELATED WORK

There are several systems intended to facilitate the grading of paper-based exams for instructors and graders, such as to provide feedback to students about the score awarded, which is sent automatically by the system to an email or to a LMS. Some of these systems appeal to the fact that only smart phones are used as the hardware component of the system. An example of this is the mobile application PGA (Programming

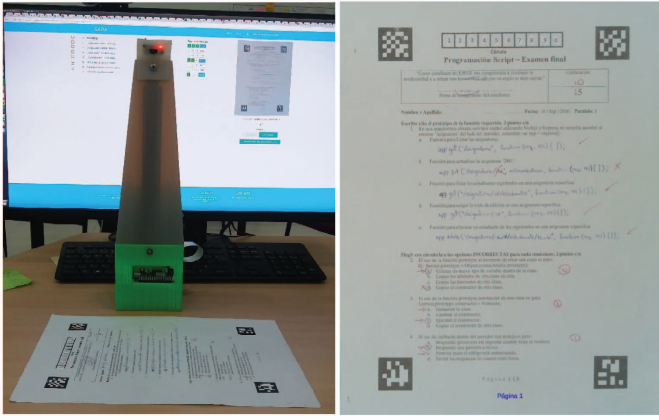


Fig. 1. The result of the page detection process while the SARA device recognizes an exam page. (ID numbers in this picture have been modified to preserve privacy.)

Grading Assistant)[5] that consists on taking photos of the paper-based exam and later grade it using the application grading interface, thus allowing the grader to give or take away points for each question depending on the student solution. The information about the student has to be provided manually. In [6], the authors propose a solution that uses a scanner and a mobile device to digitize paper-based assessments. The assessments need to have a special footer where students have to fill their identification, page, course, and some other data to identify them by the scanner. On these approaches, instructors use a web interface to grade the exams. The main difference of our system with the previously mentioned examples is that we allow the instructors to use the more natural pen-based method. Also our system does not require special actions from the students, we use optical character recognition for the identification of the student's ID and fiducial marks to recognize the assessment page, using a low-cost device under USD \$100 instead of a scanner of USD \$1000.

Another feature of our work is the use of fiducial marks placed on the corners of the paper-based exam. Other systems use fiducial marks, for example in [5], [7] the presented system places QR codes on exam pages to identify either the student or the exam question. Our system uses fiducial marks to provide a perfectly aligned and cropped digital copy of the page.

III. DESIGN DECISIONS

The implementation of SARA involved several design decisions. These decisions were:

- The grading or feedback process of the instructor should not be affected or changed: To encourage instructors and graders to use SARA, their workflow and preferences should not be altered or changed by the use of the system.
- The creation and distribution of assignment and assessment documents should be as easy as possible: The documents should be created with the same tools and procedures as before SARA. The handling and distribution of these documents should not be different from normal

paper copies (for example, the document should not be created for an specific student).

- The hardware to capture the system should be low-cost: To facilitate the adoption and sustainability of the system, the cost of the hardware should be minimal.
- The system should be plug-and-play: The system should not require calibration or complicated configuration by the instructor or grader and should not need the assistance of a technician. The system should be robust enough to handle different illumination conditions and physical setups.
- The system should work with a very low error rate: The recognition effectiveness should be high enough to avoid interfering with the normal grading and feedback process.
- The system should integrate transparently with the LMS: There should be no requirement for instructor intervention to upload the captured documents to their respective location in the LMS.

All these design decisions were taken into account to create the SARA system described in the following sections.

IV. SYSTEM AND COMPONENTS

A. Process

To use the SARA system there is a simple workflow that has to be followed by the professor:

- Design the paper-based evaluation using the preferred editor and generate a corresponding PDF file. Then, upload the file to the Fiducial Marks Generator on the SARA portal in order to add the marks and identification boxes to each evaluation page.
- Print and use the generated document in the scheduled paper-based evaluation session while asking the students to fill in their ID number in each page.
- Create the corresponding assignment on the SIDWEB (LMS used by ESPOL) where the scanned images with feedback files will be uploaded.
- Turn on the SARA device and open the Web Application from a computer on the same local network where the SARA device is connected.
- Authenticate with ESPOL credentials and choose the course and the created assignment.
- Start the capture process.
- Start the grading process of paper-based evaluations as usual while the system silently captures the graded evaluation pages.
- At any moment, it is possible to stop and start the capture process as needed and continue where it was left.
- Once all evaluations have been graded, select all the students on the web interface to upload the digitalized evaluations to SIDWEB.

The SARA system is the result of the combined work of several components (Fig. 2). These components work at the different stages of the grading and capture process. To implement the SARA system, according to the design decisions mentioned in the previous section, several components were

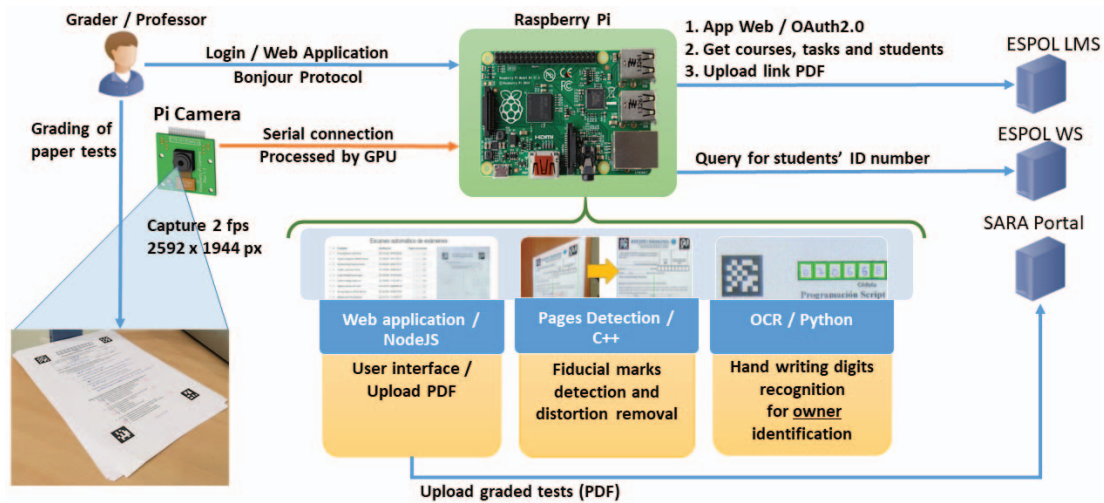


Fig. 2. System Architecture: There are 3 main components running inside the Raspberry Pi device and they all need information about the professor's courses, assignments, and students to start the recognition process.

needed. The following sections present a detailed description of these components.

B. Web Components

1) *Fiducial Marks Generator*: As per design decisions 1 and 2, the instructor should use the same procedures and tools as before, therefore the process of placing the necessary fiducial marks on the assessment document should be as easy as possible. We created an external web application that adds fiducial marks on the corners of any PDF document. The instructor needs only to generate a PDF of the assessment document and upload it to the application. The fiducial marks assist the detection and capture process. Additionally, number boxes are added on top of every page for the student to write his identification number.

To begin with the creation of the assessment, the professor has the option to download a template document from this application with the spaces needed for the fiducial marks and boxes. Once the assessment is designed, a PDF file of the document has to be uploaded to this system for the generation process. Fig. 1 shows an example of the generated PDF by this process.

2) *Monitoring Web Interface Application*: The web application is responsible for providing the system interface for the grader with feedback of the scanning process in real-time (page detected, student identified, etc.). It also allows the grader to select the corresponding course and assignment before starting the recognition process (Fig. 3). For this, the grader must use her ESPOL credentials to log into the application as it consumes REST APIs endpoints from SIDWEB, ESPOL's LMS. This allows the system to fetch and list all the courses that the grader is enrolled as a professor, the students of a course, the assignments and the possibility to send the graded evaluation PDF file as an assignment response. The last one gives the option to the students to see their exams using SIDWEB and get the feedback from the professor.

C. Hardware Component

The hardware system is composed of a Raspberry Pi 3 and a camera mounted on a 3D-printed structure with a height of 37 centimeters (Fig. 5). This specific height is a compromise between a wide field-of-view (FOV) angle to capture the entire page and a high image resolution to successfully recognize all student ID digits and markings on the page. A height of 37 centimeters provides a FOV wide enough to comfortably move and place the assessment page in any orientation below the camera (Fig. 4) while producing an image with sufficient resolution and sharp focus.

We tested using a camera with a fisheye lens to reduce the height of the structure. A fisheye lens increases the FOV angle (and therefore allows the camera to be closer to the page) but requires extra computation to correct the distortion introduced by the lens's optics. Given the limitations of the Raspberry Pi 3, this extra computation affected severely the responsiveness of the system and its user experience. In the system evaluation section the comparison of the feedback time using the fisheye lens is shown.

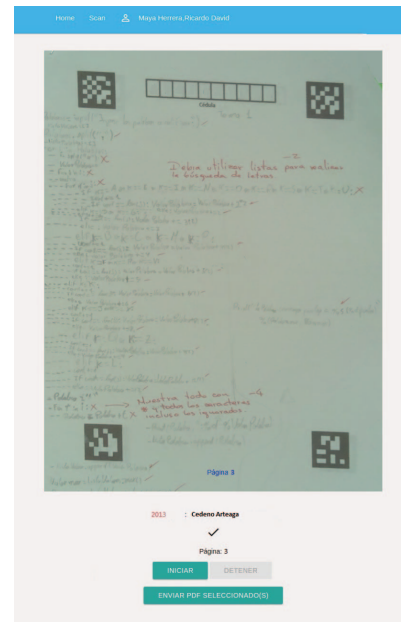
D. Software Detection Component

Our system uses several computer vision and character recognition algorithms for the correct digitalization, recognition and feedback of the assessment page in an efficient way. These algorithms are implemented by distributed processes running in the background and communicating using remote procedure calls. The main processes are explained below.

1) *Pages detection*: This component allows the identification of a page with fiducial marks using a camera and OpenCV to produce an image with a standard size and orientation with the less possible distortion, simulating a scanner process. It is based on the detection of ArUco markers [8], which allows the recognition of the near plane of the board and the generation of Augmented Reality (AR) images with the least possible distortion [9].

SARA				
<input type="checkbox"/>	#	Estudiante	Identificación	Páginas reconocidas
<input type="checkbox"/>	1	Adams Escobar	2012 - 095032	1 2 3 PDF
<input type="checkbox"/>	2	Aguiayo Quisquina	2012 - 094123	1 2 3 PDF
<input type="checkbox"/>	3	Andrade Bravo	2013 - 093070	1 2 3 PDF
<input type="checkbox"/>	4	Castillo Lopez	2014 - 092953	1 2 3 PDF
<input type="checkbox"/>	5	Castro Pefafel	2014 - 091934	1 2 3 PDF
<input type="checkbox"/>	6	Cedeno Artaga	2013 - 131243	1 2 3 PDF
<input type="checkbox"/>	7	Cedeno Cuencana	2012 - 095066	1 2 3 PDF
<input type="checkbox"/>	8	Durango Espinoza	2012 - 093057	1 2 3 PDF
<input type="checkbox"/>	9	Estrada Leon	2013 - 131042	1 2 3 PDF
<input type="checkbox"/>	10	Ferriz Alcazar	2013 - 131053	1 2 3 PDF
<input type="checkbox"/>	11	Garcia Cedeno	2011 - 091671	1 2 3 PDF
<input type="checkbox"/>	12	Guillermo Ordóñez	2013 - 092352	1 2 3 PDF
<input type="checkbox"/>	13	Idrovo Vallejo	2013 - 092487	1 2 3 PDF
<input type="checkbox"/>	14	Kuffo Rivero	2014 - 092644	1 2 3 PDF
<input type="checkbox"/>	15	Leon Moran	2014 - 092644	1 2 3 PDF
<input type="checkbox"/>	16	Loor Zambrano	2011 - 092990	1 2 3 PDF
<input type="checkbox"/>	17	Mora Cazar	2013 - 092710	1 2 3 PDF
<input type="checkbox"/>	18	Moreira Apolo	2012 - 172188	1 2 3 PDF
<input type="checkbox"/>	19	Pena Espinoza	2012 - 093056	1 2 3 PDF
<input type="checkbox"/>	20	Plascencia Jordan	2012 - 092841	1 2 3 PDF
<input type="checkbox"/>	21	Prueba Estudiante	2016 - 092005	1 2 3 PDF
<input type="checkbox"/>	22	Pulido Carrera	2010 - 092349	1 2 3 PDF
<input type="checkbox"/>	23	Ramirez Gonzalez	2008 - 092736	1 2 3 PDF
<input type="checkbox"/>	24	Santacruz Hernandez	2014 - 095223	1 2 3 PDF
<input type="checkbox"/>	25	Santana Quispillo	2015 - 095075	1 2 3 PDF
<input type="checkbox"/>	26	Sarmiento Matamoros	2011 - 092380	1 2 3 PDF
<input type="checkbox"/>	27	Velasco Mite	2011 - 092680	1 2 3 PDF
<input type="checkbox"/>	28	Yagual Meza	2012 - 095682	1 2 3 PDF

(a) Left panel



(b) Right panel

Fig. 3. A capture of how the web application system looks (some information about the students has been modified to preserve their privacy) is shown here divided in two panels. (a) The left panel contains the class roster; it specifies which pages have been recognized (colored with green) for each student. (b) The right panel contains the currently scanned page; the handwritten feedback of the professor (shown here in red) is clearly seen in the picture and therefore by the student once the page is uploaded to the LMS.



Fig. 4. A user of SARA can place the paper-based assessment in any orientation below the camera; SARA automatically corrects it.

Inside this component are used the same fiducial marks from ArUco to delimit the four corners of the evaluation but using different marks for each page, thus it can identify different pages of the same exam. After the page is digitalized, the correct homography is applied to get the page perfectly aligned. Then, the detected page number and the image are sent to the handwritten digits recognition component. By using the marker's detection process, it is possible to estimate the page position with just one marker. However, to avoid possible failures, it was established that at least three of four markers had to be recognized. Fig. 1 shows the aligned image of the digitalized page after the detection process.

2) *Handwritten Digits Recognition with OCR*: One of the most important processes in this system is the identification of the owner's evaluation in order to upload the feedback to the LMS to the corresponding student. The identification process is composed by:

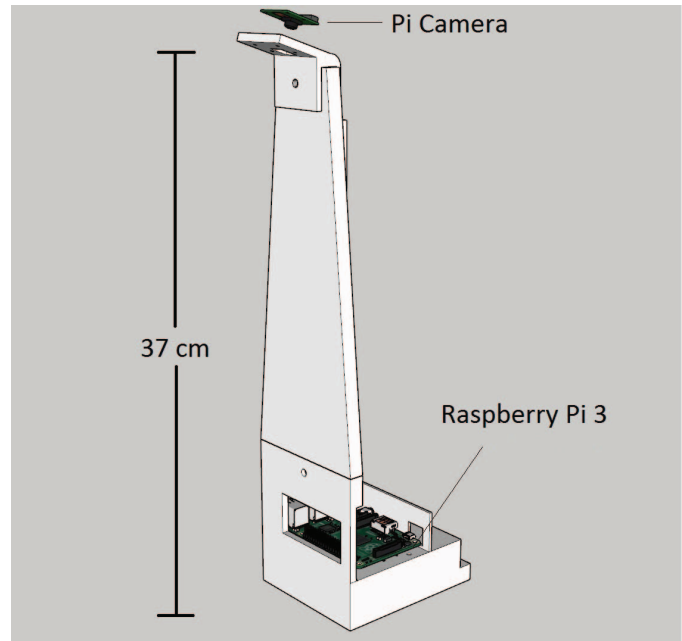


Fig. 5. 3D-printed design of the SARA prototype composed of a Raspberry Pi 3 and a camera.

- Optical Character Recognition (OCR) of handwritten digits.
- Comparison between the recognized digits and the list of enrolled students in the current course.

This component was developed in Python because of wide

TABLE I
TIME COMPARISONS BETWEEN CAMERAS

Camera	Exam capture process	Feedback
With fisheye lens	3.1 sec	4.4 sec
Without fisheye lens	1.7 sec	3.2 sec

TABLE II
PROFESSOR COURSES FOR THE GRADING TEST

Professor	Course	# Students	# Exam pages	# Total pages
professor 1	course 1	24	8	182
professor 2	course 2	30	4	120
professor 3	course 3	22	8	176
professor 3	course 4	28	8	224
professor 3	course 5	21	8	168

variety of available modules to this task. The main modules used here are Numpy, Scikit-Learn and OpenCV. Numpy and OpenCV do the recognition of boxes where digits are placed in the scanned page. Then, Scikit-Learn classifies each digit in the boxes using a linear SVM classifier[10]. The classifier was trained by a HOG descriptor [11] of 2929 images of handwritten digits.

Although, the classifier achieves a high accuracy (over 0.9), it is possible that one of the recognized digits may not be classified correctly. Therefore, it is necessary to carry out an additional search among the enrolled students in the current course. Finally, the student ID number is accepted when the Hamming distance is less than or equal to 1 with the recognized digits, otherwise the scanned page is tag as unknown.

V. SYSTEM EVALUATION

We first made a comparison of the time exam capture process which covers the image capture time, the pages detection

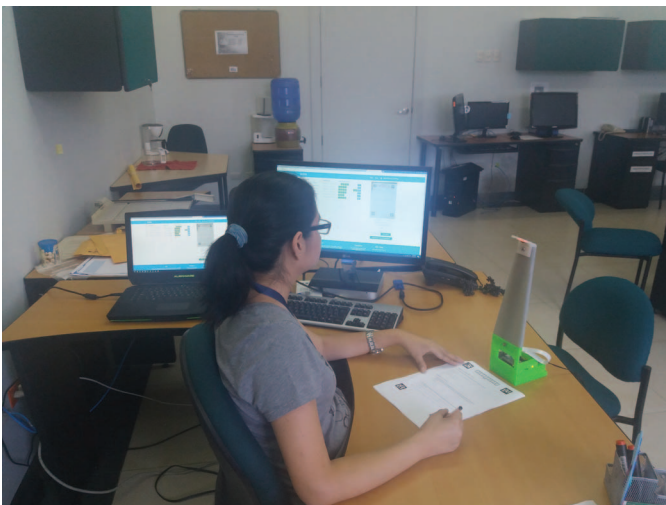


Fig. 6. A professor grading an exam using the SARA device in a real environment.

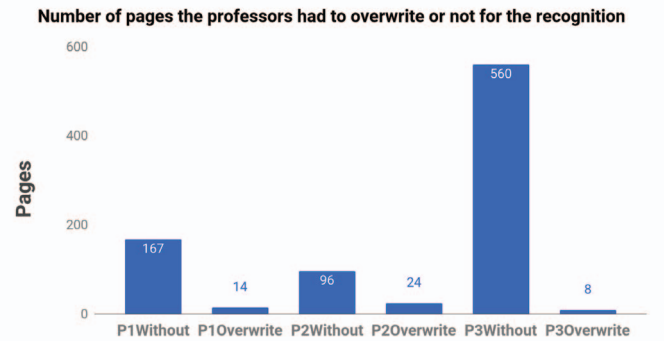


Fig. 7. Statistics about the number of pages graders had to overwrite the digits during the scanning process. (The word *without* on the horizontal axis concerns to the pages recognized without the need to overwrite the digits.)

process, and the total time until the professor can visualize the feedback of the captured exam in the web application. The results are presented in Table I where we compared the performance using a fisheye lens against a normal lens. We selected the normal lens setup and gave the SARA device to 3 professors for the grading process of their courses as we show in Fig. 6. The statistics about this data are in Table II.

A total of 870 pages were scanned by the SARA device, 869 of them were recognized correctly and one was not identified due to an OCR error. Furthermore, the professors in some occasions needed to overwrite some of the digits of some pages to aid the OCR process. Fig. 7 shows the results of this process.

VI. CONCLUSION

The SARA device allows to deliver evaluation feedback to students by digitalization of their paper based assessments. The students can access their paper based assessments feedback even if they don't have the possibility of actually getting back the actual assessment.

The digitalization process of the SARA system can recognize pages in any order allowing to grade multiple exams of different students in the order chosen by the professor. Furthermore, the digitalization isn't intrusive in the process of grading unlike other systems. Our system tries to recognize each page when it is being graded by the professor and then it puts the pages of corresponding students together in the right order into a PDF file.

The professor has to select the graded exams in the SARA web interface in order to deliver the PDF files to the students. Therefore, the professor can send the feedback in batches or at the end of the grading process.

VII. FUTURE WORK

The results of using the SARA device in real world examinations are very promising. But there are some improvements that can be made.

First, the OCR could be retrained with a bigger digits database in order to decrease the false negative rate. Nevertheless, we realized that there are some external issues like

unreadable numbers even by humans or numbers studied that can be solved only by overwriting the digits on the paper.

Second, the page detection can be made by using border detection algorithms in order to avoid the addition of fiducial marks to each page corner. Thus, the exam design would be more flexible and could have more usable space by the professor or students.

Finally, the system could be ported to IOS or Android in order to make it more accessible and be executed from mobile phones using their powerful cameras.

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REFERENCES

- [1] C. Rust, M. Price, and B. O'DONOVAN, "Improving students' learning by developing their understanding of assessment criteria and processes," *Assessment & Evaluation in Higher Education*, vol. 28, no. 2, pp. 147–164, 2003.
- [2] J. Biggam, "Using automated assessment feedback to enhance the quality of student learning in universities: A case study," *Technology Enhanced Learning. Quality of Teaching and Educational Reform*, pp. 188–194, 2010.
- [3] G. Siemens and P. Long, "Penetrating the fog: Analytics in learning and education." *EDUCAUSE review*, vol. 46, no. 5, p. 30, 2011.
- [4] M. Henderson and M. Phillips, "Video-based feedback on student assessment: scarily personal," *Australasian Journal of Educational Technology*, vol. 31, no. 1, 2015.
- [5] H. E. Murphy, "Digitalizing paper-based exams: An assessment of programming grading assistant," in *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, ser. SIGCSE '17. New York, NY, USA: ACM, 2017, pp. 775–776. [Online]. Available: <http://doi.acm.org/10.1145/3017680.3022448>
- [6] A. Bloomfield and J. F. Groves, "A tablet-based paper exam grading system," in *Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education*, ser. ITiCSE '08. New York, NY, USA: ACM, 2008, pp. 83–87. [Online]. Available: <http://doi.acm.org/10.1145/1384271.1384295>
- [7] Y. V. Paredes, P.-K. Huang, H. Murphy, and I.-H. Hsiao, "A subjective evaluation of web-based programming grading assistant: harnessing digital footprints from paper-based assessments."
- [8] S. Garrido-Jurado, R. M. noz Salinas, F. Madrid-Cuevas, and M. Marín-Jiménez, "Automatic generation and detection of highly reliable fiducial markers under occlusion," *Pattern Recognition*, vol. 47, no. 6, pp. 2280 – 2292, 2014. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0031320314000235>
- [9] S. Garrido-Jurado, R. M. noz Salinas, F. Madrid-Cuevas, and R. Medina-Carnicer, "Generation of fiducial marker dictionaries using mixed integer linear programming," *Pattern Recognition*, vol. 51, pp. 481 – 491, 2016. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0031320315003544>
- [10] J. A. Suykens and J. Vandewalle, "Least squares support vector machine classifiers," *Neural processing letters*, vol. 9, no. 3, pp. 293–300, 1999.
- [11] N. Dalal and B. Triggs, "Histograms of oriented gradients for human detection," in *Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on*, vol. 1. IEEE, 2005, pp. 886–893.