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# Time-Effective Logistics of ZOOM-Based Image Processing Laboratory

## ABSTRACT

*In "normal" time students of the ORT Braude Academic College of Engineering, enrolled to the course "Image Processing", visit frontal lectures and, additionally, participates in the laboratories provided in the class equipped with computers. During the laboratories, students (organized by pairs) are asked to implement image-processing algorithms learned during frontal lectures by writing C and C++ code. Specifically, PC with Windows 10 and Visual Studio 2019 installed, is used to write the code. Additionally to the code, students are asked to prepare PowerPoint presentation, describing the code and results obtained. During the laboratory students may ask for help and, in case of need, the educator provides additional explanations. When ready, students demonstrate the presentation and the working code to the educator and answer the questions asked by the educator. The accepted policy is that if the presentation is good enough, and students reasonably answered the questions, they get a grade and, as a backup, E-Mailed a presentation and the code by using the special format developed specifically for that course. However, because of COVID-19 limitations, laboratories were requested to be executed by using ZOOM, and then, some of the elements of this logistics became problematic. Hence, the following changes were provided: students work by using their PC while being connected to the ZOOM. Students may still ask the educator for help. However, when ready, they E-Mailed the prepared presentation and the code to the educator by using the special format modified for the online laboratory specifics. During the laboratory educator monitors a specific E-Mail address and checks presented reports. Additionally, the educator checks if the code works. In case of problems, the educator asks for rework. The policy is that at the end students are expected to create a reasonably good report, and thus, to achieve a high grade. This logistics was tested during three semesters and was found to be adequate for the goals of the course.*

**Keywords:** *ZOOM-based laboratory, STEM, image processing, logistics, e-learning*

## Introduction

Our days, image processing algorithms and techniques are widely used in many fields of science and technology. The wide proliferation of digital cameras created new applications in which the usage of image processing techniques becomes a must. Even the simplest smartphone our days contains a number of digital cameras and images, grabbed by those cameras, only rarely are presented without some processing. Practically, image processing algorithms are implemented as software or as firmware. Hence, one can conclude, that applications dealing with images are to be created by programmers. However, anybody skilled in the art knows that without understanding how exactly a digital camera creates an image, effective implementation of even the simplest image processing algorithms is practically impossible. For example, in order to use Fast Fourier Transform, the acquisition system must be linear. Practically, every electronic engineer knows that CCD cameras are linear, whereas CMOS cameras are not linear, but most computer specialists are not aware of this fact. This is why in the field of image processing un-proportional number of software (and hardware) developers are actually electronic engineers. And, this is why the image processing course is an important part of the education of modern electronic engineers. Typically, this course is provided after students pass advanced mathematical courses and basic signal processing courses.

An important part of the image processing course is a computer laboratory. It is assumed, that in the frames of the laboratory students practically implement and explore algorithms and techniques that were studied in the frames of frontal lectures. 30-40 years before home computers were not powerful enough to execute even simple image processing algorithms. Then, PC was hardly an option: the typical memory size of AT PC in 1990 was 640 kB - less than needed to load a true color VGA image to the RAM. Hence, then, expensive specialized computers were needed to provide an image processing laboratory. For example, at 1995-1999 in the ORT Braude Academic College of Engineering (Karmiel, Israel) image processing laboratory was provided by using very expensive (but powerful) Silicon Graphics workstations. In those days creation of the digital image to be processed by a computer was not a simple task – expensive digital camera with a specially designed connector must have been used. Obviously, then, providing an image processing laboratory was possible only at specially equipped computer class. The goal of the educator then was to monitor students' activity during the laboratory and assist in solving technical problems. Grading was plain and simple – to check reports prepared during the laboratory and ask a number of questions in case of need.

After 2000, expensive Silicon Graphics workstations were replaced by inexpensive PC with Windows operational system. Digital cameras still were considered as expensive professional equipment. Compilers (of Borland and of Microsoft) were expensive, so that the only option to write the code and test it was to use the equipment of the specialized computer class. Now, the situation is different: nearly every student can afford a laptop with Windows OS installed, Microsoft Visual Studio is free for noncommercial usage, digital cameras are an inherent part of the laptop, and, in case of need, an inexpensive USB camera can be used to grab images to be processed by the software developed by students. This technology progress enables to reorganize image processing laboratory: significant parts of the laboratory assignments can be done out of a specialized computer laboratory.

When COVID-19 restrictions become a reality, and when ZOOM frontal lectures were found as a bearable option, the next step was nearly obvious: try to provide an image processing laboratory out of the specialized computer class – by using student' laptops. It is obvious, that to make this approach practical, significant logistics changes were asked to be done. The rationale and details of logistics procedures that were used to provide image processing laboratory by using cloud techniques during the last 3 semesters are discussed in the following sections.

## Literature Review

The organization of laboratories as an important part of engineering education is an item studied by a large number of educators. Different aspects of this organization are widely discussed at the conferences.

An important aspect of the laboratory organization is how laboratory reports are created, stored, and graded. Obviously, writing reports on paper cannot be considered as an option our days. Many computer-based utilities can be used as a paper replacement. For example, well-known "Evernote" software was used to create electronic laboratory notebooks (ELN) (Walsh & Cho, 2012). Another example is the use of Google Docs cloud service to effectively manage the data generated by many students. An important feature of this service is that files stored in the cloud are not processed by the local (client) computer, but by using cloud computing. This approach provides effective solutions for a number of data-management problems (Bennett & Pence, 2011).

Many universities were able to successfully provide a number of laboratories (or parts of them) remotely (Auer & Gallent, 2000).

A number of articles discuss specifics of the image processing laboratories – provided at the campus and by using cloud techniques (Rashid, 2020).

COVID-19 situation forced to modify laboratory procedures that were used many years, and these modifications were required to be done in the extremely short period of time – days. It is clear, that in the near future a large number of articles will discuss which changes were successful and which not.

Problems of laboratory organization, laboratory results reporting, grading were intensively studied many years at Braude Academic College of Engineering (Kosolapov & Sabag, 2009a, 2009b, 2015). In this paper modifications introduced to an organization of the image processing laboratory because of COVID9 situation will be described and discussed.

## Methodology

*Logistics before COVID-19 Limitations*

In a "normal" (non-COVID-19) times students of the ORT Braude Academic College of Engineering, enrolled to the course "Image Processing", visit frontal lectures, and, additionally, participates in the laboratories provided in the class equipped with computers. During the laboratories, students (organized by pairs) are asked to implement image-processing algorithms learned during frontal lectures by writing C and C++ code. Specifically, a PC with Windows 10 and Visual Studio 2019 installed, is used by students to write the code. Additionally to the code, students are asked to prepare PowerPoint presentation, describing the code and results obtained. During the laboratory students may ask the educator for help and, in case of need, the educator provides additional explanations. When ready, students demonstrate the PowerPoint presentation and the working code to the educator and, in case of need, answer the questions asked by the educator.

The accepted policy is that if the presentation is good enough, and students reasonably answered the questions, they get a high grade and, as a backup, students E-Mailed the presentation and the code by using a special format developed specifically for that course. The goal of this special format is to enforce time-effective logistics: students are bounded by strict reporting rules that must be explained at the first laboratory, but the educator spent minimal time to evaluate the report and code, so that the grading procedure is relatively fast, uniform for all assignments and is assumed to be clear to the students.

The developed format states that file names of the reports, zip files and subjects of Emails contain the sequence “ABCD-EFGH-YYYY-MM-DD-QR-STUV” (later referred to as “the sequence”). A pair of students must replace all “big letters” to digits (as explained in the next sentence). The delimiter between elements of “the sequence” was selected as “-”. Important, that this symbol can be used as part of the file name. Usage of delimiter to create a template for a fast search of the requested report in Gmail is obvious.

Sub-sequence “ABCD” is to be replaced with the last 4 digits of the ID of the first student, sub-sequence “EFGH” is to be replaced with the last 4 digits of the ID of the second student. Last, and not the first digits of the ID, are used because they are effectively random numbers. To prevent ambiguity, it is requested that numerically ABCD < EFGH, so that the order of students (who is “the first student” and who is “the second student”) is dictated by the last 4 digits in their IDs. However, this order has no influence during the conversation with the students and on grading.

Sub-sequences “YYYY”, “MM” and “DD” are to be replaced, correspondently, with the year, month, and day of the report. This order effectively creates auto sorting by date of report. Sub-sequence “QR” is replaced with the number of the assignment. To make a search template consisting, sub-sequence “QR” always consists of two digits, so that for “Assignment 1” sub-sequence “QR” is “01”, for “Assignment 2” sub-sequence “QR” is “02”, etc. Sub-sequence

"STUV" is replaced with some number generated by using any appropriate one-way function and is used as a simple replacement to electronic signature.

For each specific assignment designed for the current semester, the lecturer prepare PowerPoint template. This file contains a detailed description of what exactly must be done in the frames of this assignment. When a pair of students begins to execute a specific assignment "QR", they download from the site of the course relevant "QR" file named as: "ABCD-EFGH-YYYY-MM-DD-QR-STUV. pptx" and immediately replaces all the sub-sequences except "STUV" to digits as explained above. The template contains a number of specially numbered slides. For example, "Assignment 1" was about creating some synthetic image. Then, the template has the slide numbered as "1.1". This slide contains some exemplary image and some "strange" text written by using letters and symbols of the red color. During the execution of this assignment, students are requested to replace this exemplary image to the image that they created during the laboratory and to replace "strange" red text to meaningful black text. When students demonstrate this specific slide to the educator on the computer screen, it takes only several seconds to evaluate if the image was created in full accordance with requirements, and if the black text explains the created image well enough.

In the frames of developed time-effective logistics, finished and graded reports and the code developed by students are to be sent to cloud-based Email. The number of reports to be sent during the semester is large, hence, practically, a special Email – dedicated to this laboratory only is used. To prevent possible misunderstandings considering laboratory grading, Email has a special format goal of which to log relevant grading steps in the cloud. It was found that cloud-based Gmail is good enough for this goal.

When a specific pair of students finished executing all the requirements of, say, "Assignment 1", they open PowerPoint presentation they created and open the Visual Studio project (containing the code they created). Additionally, one of the students of the specific pair of students opens the Email application, and fill the Email address dedicated to this laboratory and add (in the "CC" field of the Email) the Email address of the second student. Then "the sequence" with still not changed "STUV" subsequence is typed in the "subject" field of the Email. When ready, students of this pair asked the educator to arrive to their computer. The educator passes the presentation slide by slide. In case of need, the educator may ask students to make some changes in the code they wrote, recompile it and run – to ensure that it works and create images as required.

This course has a specific grading policy: if e educator is not fully happy with the presentation and the code, students are asked to rework the presentation and/or the code, else educator (by using a simple application on his smartphone) generate "STUV" number and students updated "the sequence" in the "subject" field of the Email and in the file name of the PowerPoint presentation.

If asked, students may additionally add a zip file with the Visual Studio project. Generally, students are instructed which files can be safely sent by Email and which not. Typically, students are sending "zip" file with "h" and "cpp" files and "sln" and "proj" files inside. The file name of the "zip" file is "the sequence" with the ".zip" extension. Important request here is that by using this zip file the educator may check if the student's code can be compiled, liked, executed, and if the "exe" file created in the educator' computer creates images that were discussed in the PowerPoint presentation attached to the Email.

Important, that students are requested to send Email while the educator is still near their computer. This requirement prevents most of the possible future misunderstandings.

It is clear, that with this grading policy most students, at the end, are getting the highest grades for this laboratory. However, it must be noted, that this highest grade is granted after hard work and after the educator validates that students understand important details of the algorithms learned and of the code they wrote. Still, some students were not able to do all the chores, so that not all students have got high grades for this laboratory.

*Changes in Physical Presence Policy*

According to the college rules, the physical presence of the student in the laboratory provided in the campus, for obvious reasons, is an academic must. However, in recent years, many students started to prefer to use their personal laptops instead of computers in the laboratory. It was found, that this practice has some advantages: for example, the laboratory room is less crowded during the laboratory. When a specific pair of students is ready to present PowerPoint presentation and working code, then this pair of students physically arrived to the laboratory room for regular grading procedure.

Additionally, there were situations when some students were not able to be physically present at least at some laboratories. In some situations, some students (after considering their' situation) have got a special permit to send Emails with "STUV" subsequence set to "0000", so that the educator was able to see that those presentations did not pass the regular grading process. Effectively, this procedure was a simplified variant of e-learning, and it was found that this updated procedure is more fair than no grading for missing laboratory.

*COVID-19 Limitations*

Starting from the spring semester at 2020 our college is working with COVID 19 limitations. In the frames of these limitations, all laboratories (if possible) were requested to be executed by using ZOOM, and then, some of the elements of the logistics that were used starting from 2007 became problematic.

Considering the experience we have got by resolving "special situations" described above, and after 3 days granted by the administration of the college for the "feasibility checks", it was decided, that this specific image processing laboratory can be provided remotely by using cloud-based services like ZOOM and Gmail. Other cloud-based services like MOODLE were found less attractive in this specific case.

*New Cloud-Based Logistics*

Exactly, as some students in some specific situations were permitted to work from any place, now all the students were permitted to work from any place providing that reliable Internet connection was available at that place. Practically, because of lock-down, students and the educator worked from their homes by using their personal computers. At a due time educator started the ZOOM session and permit to students enrolled to the laboratory to get access. To exclude non-pleasant situations of non-authorized access, waiting room access was used, so that the educator can see who is asking "to enter". At the beginning of the laboratory, the educator explains what must be done and explains details of the specific template. Considering that student's personal computers and laptops in most cases are not very strong, and by taking into account that Visual Studio requires significant resources, students were allowed to disconnect from ZOOM session, or at least disable their cameras. At any moment students were able to reconnect to the ZOOM session and ask the educator for help. In case of need, the educator permit to the students to share the screen of their computers and demonstrate to the educator problem they revealed. The usage of "rooms" was found to be too complicated for this specific laboratory, so that other students were able to follow the current discussion or to concentrate on their work.

*Changes in Reporting Laboratory Results*

Despite it was possible to ask students to work on assignments in an individual fashion, it was decided, that students will work in pairs, as in the "normal" situation. When ready, a pair of students Email the prepared presentation and the code to the educator by using the special format described before. However, "the sequence" was stripped of the "STUV" sub-sequence.

*Changes in the Grading Procedure*

During the laboratory, the educator works by using at least two personal computers. The first computer runs the current ZOOM session. The second was used to monitor dedicated Gmail and check student's PowerPoint presentation and code. On arrival of the new Gmail, the educator opens PowerPoint file in the browser window. No downloading is required in that case. Additionally, the educator use Excel file to summarize students' achievements. While reading the current PowerPoint presentation, the educator compares the original template with the student' report, and, thus can compare what was asked and what was done. In case of suspicion that code is wrong, the educator can unzip zip file containing Visual Studio project, recompile it and run in order to validate that code works as required. In the case of good report and working code, the educator answered to the student's e-mail by a simple and short message: "Report 1: OK". Then students and the educator updated their Excel files to see current laboratory grade. In case that the educator reveals problems in the presentation and/or in the code, request for rework is emailed to the relevant pair of students. After getting a rework request, in most cases, students reconnected to the ZOOM session and asked for clarifications.

## Results

Updated ZOOM-based logistics were tested during the three last semesters. Taking into account that all laboratories were forced to be provided by ZOOM, it was impossible to organize a control group in order to compare if updated logistics provide better results or not. By comparing the level of student's presentations and the complexity of the code with those of "normal" semesters, it can be stated that the level of the presentation and the level of the code were not significantly changed. However, considering the situation, it is clear that no valid statistical analysis can be provided in that case.

## Discussion

Modified ZOOM-based logistics were found reasonably time-effective from the educator's point of view. Typically, grading one assignment takes less than 1 minute if the report and code were found as "good enough". However, processing of "problematic reports" took more time – especially for explaining the errors. Hence, it was decided to immediately stop the checking process if serious problems with the presentation and/or code were found. In that case, rework was requested. In order to prevent the unlimited number of "reworks", the number of reworks was set to 5 for the first assignment (to enable students to learn the level of requirements), but for the following assignments, the number of possible reworks was set to 2. It was assumed that after the second rework grade for the specific assignment will be less than maximal. However, all the students quickly grabbed the meaning of this limitation, and, at the end, all reports have got maximal grades. Still, a number of students did not send all reports, and, in that case, the final laboratory grade was significantly less than maximal.

During "COVID semesters" it was found unpractical to collect students' opinion (students' feedback) about specific courses officially. Hence, this parameter cannot be used to evaluate the quality of the selected cloud approach. However, privately, students claimed that this specific laboratory can be provided by using cloud services.

## Conclusions

Modified logistics of cloud-based image processing laboratory were found reasonably time-effective. Its usage enabled to continue the educational process without interruption.

Cloud-based courses have some obvious advantages and some disadvantages. The most striking disadvantage is that the educator cannot be aware that specific students executed all laboratory assignments without external assistance. Additionally, it was practically impossible to evaluate if the work was equally distributed between both students of the specific pair.

Still, developed logistics can be considered as a preliminary prototype of a remote image processing laboratory. It is clear, however, that more R&D work must be done to arrive to statistically valid conclusions if remote laboratories can be good enough compared with "regular" in-campus laboratories.

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