

## Time Effective Logistics of Hybrid Image Processing Course and Laboratory

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*In “pre-COVID 19” time, Braude Academic College of Engineering students enrolled in the course “Image Processing”, visited frontal lectures, and, additionally, participated in the laboratories provided in the class equipped with computers. During the laboratories, students (organized in small groups – preferably by pairs) were asked to implement several image-processing algorithms explained during frontal lectures. In the frames of this course, C, C++, and C# languages are used to write code. Specifically, to write the code, students used computers with Windows 10 and Visual Studio installed. Additionally, students were asked to prepare a PowerPoint presentation, in which they were asked to analyze the results obtained. During the in-campus laboratory, students were free to ask for help, and, in case of need, the educator provided relevant explanations. When the report was ready, students demonstrated the presentation and the working code to the educator. The grading policy was that if the presentation was good enough, and if students reasonably answered the questions, they got a high grade. As a backup, students E-Mailed a presentation and the code by using a special format developed specifically for that course. Because of COVID-19 limitations, during three semesters logistics of the lectures and laboratories were changed, and, as lectures, as laboratories were provided online by using cloud services like ZOOM and Gmail. It so happens, that semester 2021-10 – 2022-03 was started as an online semester, but after three weeks, it became a hybrid semester: lectures and laboratories were provided in-campus, but students had the right to stay at home and continue to use cloud services including ZOOM and Email. This change created a number of logistics problems, and, thus, some modifications were provided in an attempt to ensure fair and non-biased grading as for the students who were physically present during the lectures and laboratories, as for the students who participated remotely. In the frames of this course, each group of students prepared a set of assignment reports and two micro-project presentations. Additionally, students physically present in the class, participated in the short nonobligatory micro-exams. This paper discusses logistics decisions and their effect on the quality of the students’ micro exams, assignments reports, and presentations.*

**Keywords:** hybrid laboratory, STEM, image processing

### Introduction

Digital cameras, image processing algorithms, and hardware and software image processing techniques are widely used in many fields of science and technology. Today digital cameras are everywhere. Digital cameras are physically integrated into many gadgets, from smartphones to digital watches. Hence, a number of software applications for storing, processing, and analyzing images are available. In order to get “the best image”, modern smartphones have a number of digital cameras, each of them having different characteristics, so that even in the

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simplest cases, images pass some preliminary image processing procedures. Image processing algorithms can be implemented as a software, as a firmware. Hence, it can be concluded, that applications dealing with images are to be created by programmers. But, anybody skilled in the art knows, that in order to develop memory effective and fast image processing utilities, a deep understanding of how exactly a digital camera creates an image is required. Well-known example of why a deep understanding of camera operation on the electronic level is a must is a situation when Fast Fourier Transform approach must be used. Every electronic engineer knows that CCD cameras are linear – that is: digital response is proportional to the light intensity, and that CMOS cameras are not linear in that sense; however, most software developers that did not learn basic electronics are unaware of this fact. From this, one can understand why in the field of image processing un-proportional number of software (and hardware) developers are, actually, electronic engineers. Hence, the image processing course is an essential part of the education of modern electronic engineers. Most universities provide this course after students pass advanced mathematical and introductory signal processing courses.

An essential part of most image processing courses is a computer laboratory. During the laboratory, students practically implement and explore algorithms and techniques that they studied during frontal lectures. In the “early computer days” (30–40 years before), specialized and expensive computers were needed to process images. For example, the memory of a typical PC then was less than 640 kB – so that processing of even one true color VGA image was a challenge. Those days providing an image processing laboratory was possible only in specially equipped computer class. Then, in the Braude Academic College of Engineering dedicated class equipped with expensive Silicon Graphics computers was used to provide the image processing laboratory. The digital camera then was a costly device, so that only two stations were equipped with a digital camera. The educator then monitors students’ activity during the laboratory and helps in solving software and hardware problems. Obviously, there were a lot of interactions between the educator and students, so, at those times, laboratory logistics and grading process were plain and simple.

In 2005, expensive Silicon Graphics computers were replaced by a less expensive PC with Windows operational system. Still, digital cameras and compilers needed to create working code were expensive; hence specialized computer class was still needed.

Our days, the situation is completely 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 get images to be processed by the software developed by students. It is the technology progress, that enable dramatically reorganize the structure of the image processing course for the electronic engineers: specialized laboratory is not a must for the modern image processing course. Practically, starting from 2005, most students prefer to use their laptops instead of computers installed in the image processing laboratory. Then,

small, but important change in the presence policy become a must: in the days of the “dedicated laboratory”, the presence of all the students in the laboratory in order to do assignments was an obvious must. But in the situation when student by using the personal laptop can do all the assignments at any place, the requirement of 100% presence in the image processing laboratory became outdated. Then, the logistics of the image processing laboratory was reworked on the basis of cloud-based reporting: students can work at any place, by using specially prepared templates they prepare a report for each assignment, and send report by Gmail to the educator. Special efforts were made to make this logistics transparent and time-effective, as for student, as for educator, so that time needed to create, manage and grade the reports will be minimal.

In 2020 COVID-19 restrictions become a fact of life. Providing frontal lectures by ZOOM was found as a possible option. It was also found, that by using ZOOM, an educator can monitor students' activity during laboratory hours from a remote place nearly without changes, while the internet connection was stable.

Still, significant logistics changes were asked to be done to make a cloud-based approach practical. The rationale and details of logistics procedures that were used to provide the image processing laboratory by using cloud techniques during the last five semesters (part of them were under COVID-19 restrictions, part – hybrid) are discussed in the following sections.

## Literature Review

Practical aspects of the laboratory's organizations were reported in many articles and discussed at many conferences.

Many educators discussed the ways how laboratory reports are created, stored, and graded. Writing reports on paper these days is considered an outdated and non-reliable practice. Many computer-based utilities can be used as a replacement of paper-based reporting. For example, well-known “Evernote” software was used to create electronic laboratory notebooks (ELN) (Walsh and 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 and Pence 2011).

Some universities successfully provided a number of laboratories (or parts of them) remotely (Auer and Gallent 2000).

Specifics of the image processing laboratories – provided at the campus and by using cloud techniques were discussed (Rashid 2020).

COVID-19 situation stimulated modifications of laboratory logistics that were in use for many years, and these modifications were asked by the administration of universities and colleges to be done in an extremely short period of time – days. It can be expected 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, and grading were intensively studied many years at Braude Academic College of Engineering (Kosolapov and Sabag 2009a, 2009b, 2015). This paper compares logistics used for the organization of the image processing laboratory in a “normal” semester, in a COVID-19 semester, and in “hybrid” semester (in which one part of the students were present at the campus, whereas another part of the students were permitted to work from their homes). Some elements of this time-effective cloud-based logistics were described before (Kosolapov 2021, 2020). This paper provides additional details concerning logistics modifications used in the “hybrid” semester.

## Methodology

### *Logistics before COVID-19 Limitations*

In a “normal” (before-COVID-19) semesters students of the Braude Academic College of Engineering, enrolled to the course “Image Processing”, were expected to visit frontal lectures (albite physical presence on the lectures was not a must), and, additionally, participates in the laboratories provided in the class equipped with computers (physical presence in the laboratory during laboratory hours was a must). During the laboratories, students (organized by pairs) were asked to practically implement image-processing algorithms learned during frontal lectures by writing C and C++ code. Specifically, a PC with Windows 10 and a free community version of Visual Studio 2019 were used by students to write the code to be compiled as an “exe” file that can be run by any computer running Windows 10 OS. In addition to the requirement to write the code that can be compiled, linked, and executed, students were asked to prepare a PowerPoint presentation describing the code and the results obtained. To make grading of the reports simple, fair, and time-effective for the educator, for each laboratory assignment, the educator prepared a special template with clear items to be addressed. In a “normal” semester educator is physically present in the laboratory room, so that during the laboratory, students are permitted to ask the educator for help, and, in case of need, the educator provides additional explanations. When ready, students demonstrated the PowerPoint presentation and the working code to the educator and, in case of need, answered the questions asked by the educator.

The accepted grading policy was that if the presentation was good enough, and students reasonably answered the questions, they have got a high grade. 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 was to implement time-effective logistics. Students were bounded by strict reporting rules that were explained at the first laboratory. Gmail based reporting rules are explained in the next section “Structure of Gmail based report.

### *Logistics under COVID-19 Limitations*

From the spring semester of 2020 until the spring semester of 2022, Braude College was working under 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.

After three 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.

### *Details of Cloud-based Logistics by Using ZOOM*

Exactly, as in “normal semesters”, some students in some specific situations were permitted to work from any place; now all students were allowed to work from any location, providing that a 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 due time educator starts the ZOOM session and permits to students enrolled to the laboratory to get in. To exclude non-pleasant situations of non-authorized access, waiting room access was enabled, so that the educator could see who was 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 powerful, 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.

### *COVID and Hybrid Semesters: Changes in Physical Presence Policy*

According to the college rules, the physical presence of the student in the laboratory provided in-campus is an academic must. However, starting from 2005, many students preferred 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 was ready to present PowerPoint presentation and working code, then this pair of students physically arrived to the laboratory room for regular grading procedure.

By using experience obtained during COVID-19 semesters, it was decided, that requirement of physical presence can be not strict as before. Then, in a hybrid semester students were provided an option –to be present in the class, or work from

another place by using ZOOM. At any case, students were required to send the report by using Gmail based procedure described in the following sections.

### *Changes in the Grading Procedure*

In the COVID-19 semesters, grading laboratory reports by direct interaction with students was found non-realistic, even by using ZOOM. Hence, the educator graded student's work by reading and evaluating reports only. To make grading fair and consistent, the educator created Excel files containing clear criteria for a fixed number of items to be addressed in the specific report. An example of those items will be described in the section "Example of Grading by Items". While grading the reports, the educator add points in Excel file and, in case of problems, lower the grades for the specific item and add a comment in the relevant cell. To make grading time-effective, numbered lists of typical errors were used – the comment refers to the number of the error – much less typing for the educator. Additionally, students were able to understand without interaction with the educator why their grade was lowered. In some situations, students were permitted to present an additional version of the report and improve their final grade.

### *Structure of Gmail Based Assignment Report*

Sending a report by email looks like a simple procedure. However, if students send reports without a specific format, the educator will spend a lot of time sorting, managing, and grading those reports. This is why part of the time-effective logistics is a strict structure of the email fields. Long ago it was decided to use Gmail as a mail server for the developed then logistics. The reasons then were: Gmail was the first free cloud-based email server (that is, all emails were accessible from any computer), and from the early days, Gmail has had excellent sorting tools. A number of Gmail accounts were possible to create without problems. Hence, in order to prevent cross-talk between different courses, it was decided that every course, that will use a specific variant of this cloud-based logistics, will be operated by a dedicated Gmail account – with the different account name and different password.

Table 1 describes the structure of the Gmail-based report. Field "To" contain account name of the Gmail dedicated to this course. For security reasons, real name of the specific account will not be revealed here, hence "\*" symbols are used to hide parts of the account name. Important to mention: this specific Gmail address is used for sending reports only. During the laboratory, students work by pairs. When one of the students sends a report to the educator, it is a strong requirement to fill "CC" field (carbon copy) by typing college' Email of the second student. Additionally, second student is asked immediately validate receiving this specific report, download all attachments and validate that they contain all materials required. This simple requirement effectively prevents "false" student' claims that the report was send, but the educator claim that it was not sent. In this situation, an

educator may ask the second student to send a “screenshot” of his/her email application.

Field “Subject” contains a specially designed E-Signature – a set of alphanumeric tokens to be modified specifically for every assignment. In the frame of the Image Processing Laboratory, there are two types of assignments: Laboratory assignment and Micro Project assignment. Specifically, last semester there were 12 laboratory assignments and two micro-projects. The structure of the E-signature for the case of laboratory assignment is described in Table 2. The structure of the E-signature for the case of Micro Project is the same except token #3 – it was “MPYN” instead of “QR”, where Y was 1 for Micro Project 1 and 2 for Micro Project 2. N was a number in the list of Micro Project subjects.

Field “Text” was not used in the frames of this logistics. Educator was not expected to waste his/her time by reading “free text” written by students. But, in order to comply with Gmail security rules (Gmail without subject go to “Junk”), some text was asked to be added. For example: “Assignment 11 finished”.

The report and other files to be used for the grading are combined in the zip file having the same name as the “Subject” field. Specifically for the Image Processing course, files inside zip file can be used to recreate executable written by students. To do this, the educator must unzip the attachment, double-click the “sln” file, and then press the F5 button. In case a valid executable is not created, then the assignment is rejected. PowerPoint Report can be opened without the need to unzip zip file.

An important part of the grading is feedback – some remarks that the educator sends to the students. Again, being non-standardized, this feedback may quickly become time-consuming for the educator. In the frame of this logistics, the only possible feedback for the laboratory assignments that is sent from this Gmail account back to the students is “Assignment QR OK” or “Assignment QR wrong” (QR stands for the laboratory assignment number). Micro Project reports are not answered. Details of the feedback in this case will be discussed later. Reports containing Gmail that has wrong “Subject” (not in accordance with requirements) are ignored and never opened. Again, this Gmail is never used for time-consuming discussions. Details of time-effective grading and time affective appeals processing for the grades set by the educator will be discussed in the following sections.

#### *Naming Rules for Laboratory Assignment*

Additional important elements of the logistics are strict reports naming rules. The goal of these rules enables fast management of the reports sent by students. Table 2 contains the exemplary description of tokens (short set of letters and digits) used to name Laboratory Assignments. Important to understand, that ‘-’ character is used as a delimiter between tokens (See Table 1). Using delimiters significantly simplifies the search in Gmail.

**Table 1.** Structure of the Gmail Based Assignment Report

Gmail Field	Example	Comment
To	*ImProc*@gmail.com	Dedicated Gmail. Used for cloud-based reports only
CC	MosheX@ebraude.ac.il	College Email of the second student
Subject	ABCD-EFGH-QR-X  or ABCD-EFGH-MPYN-X	E-Signature for Laboratory assignments - see Table 2 for details or E-Signature for Micro Projects
Text	Assignment 11 finished	Some text is a must for legal Gmail - to discard spam
Attachment	ABCD-EFGH-QR-X.zip or ABCD-EFGH-MPYN-X.zip	zip file must contain PowerPoint presentation having the same E-Signature name as a subject and at least the following files: *.h, *.cpp, *.sln, *proj. In case of need, BMP images are to be added.

In Table 2, one can see that the first token is ABCD –those four letters are to be replaced by the last four digits of the first student's ID. Full ID in Israel contains 9 digits, but for security reasons, only four last are used. It is the latest and not the first digits that are used, because they are more “random”. The second token EFGH contains four last digits of the second’ student ID. To prevent ambiguity, the rule is: ABCD < EFGH, hence it is clear which student is “the first” and which is “the second”. In the frame of this logistics student’ names are never mentioned in the reports. Hence, when grading the reports, the educator do not know who those students are, hence, who is “the first students” in this specific pair, and who is “the second” – has no influence on the grading.

Token #3 “QR” decodes the number of the assignment. Token #4 “X” encodes the number of the report’ version. Current policy is to permit a number of report’s versions. As a first step a pair of students send the report with X=1. In the case the report was found “correct”, they receive the feedback: “Report OK”. In case of problems, they can see errors in the dedicated Excel file. Then, students have an option to send an additional (corrected) version. For the first assignment 11 three versions were permitted to send. For other assignments, only two versions were allowed to send. It is clear, that with this “soft” policy, most of the grades will be maximal. It must be taken into account, however, that high grades were not granted “for free”, but after the hard work of the students.

**Table 2.** Naming Rules for the Laboratory Assignment

Token #	Token Template	Comment
1	ABCD	Four last digits of the first’ student ID
2	EFGH	Four last digits of the second’ student ID



3	QR	Number of assignment: 11,12,13,14 21,22,23,24 31, 41, 51, 52
4	X	Number of Laboratory Report version X = 1,2,3 for QR = 11 X = 1,2 for other assignments

#### *Example of Grading by Items*

Fair and consistent grading by reports only is always problematic. Hence, report templates contained a list of clearly defined items to be addressed in the report. Of course, details of those items were explained to the students at least twice (in the frontal lecture and in the laboratory). Exemplary details of “grading by items” are presented in Table 3.

In this specific example, pair of students is required to create the function “AddGrayRectangle”. In the lecture, the lecturer explained the “blending technique” – how to add an object to the image while not exceeding byte ranges. Additionally, in the lecture concept of “clipping” was explained – what to do if the object to be added partly or in full is out of the basic image ranges. Students that did not understand those concepts will not be able to fulfill the requirements of the items 2 and 3 of Table 3. From the logistics point of view. An educator immediately (in seconds) will reveal if students understand the above concepts or not. Again, from the logistics point of view, an educator must not type long explanations of what was wrong: considering. That error of that type is a typical and “predictable” error; hence, this error is a good candidate to be included in the “list of errors”, so that an educator must only add the number of this error in the list in the relevant cell of the Grading Excel File. It is clear, that creating “list of errors” is not a simple task, but over the years of using, this list became more stable. Additional important part of fair grading is that when the error is in the “list of errors”, an educator lowers the grade in the same way for any pair of students. This, effectively, eliminates most of “appeals” for unfair grading.

One of the requirements is that students will add all files needed to recreate executable file that will create all requested images. However, opening the project, compiling it, and running the executable require some time – minutes. The requirement to add the code of the function “AddGrayRectangle” to the PowerPoint presentation enables to the educator to see the code immediately. It is assumed, that the educator is skilled enough to understand if the code good enough or not. In case the code is not in full accordance with the requirements, an educator marks the assignment as “having problems” and asks the relevant pair of students to rework the project. Obviously, in this case, there is no need to start the time-consuming process of testing the project for the current version of the report.

An important requirement was that created code really works – this requirement prepares students for the actual work in the industry – where an obvious requirement is that the “product must operate as described”.

Important to understand, that described procedure of grading by items, does not require direct contact between students and the educator, and, thus, can be used as in “normal semester”, as in “hybrid semester”.

**Table 3.** *Example of Grading: Laboratory Assignment 11*

#	Item	Points
1	Put YOUR resulted image “grayImage11.bmp” <i>and add short comment what the educator is expected to see</i>	1
2	Put Relevant Profiles Here. <i>(to prove that image “grayImage11.bmp” was created as required)</i>	2
3	Code of the function “AddGrayRectangle” <i>With proper comments</i>	2
4	Proof that the function “AddGrayRectangle” works as described (use scientific tools)	2
5	Code of the “main” function	2
6	What did you learn?	1
	<b>Total</b>	<b>10</b>
A	Code cannot be compiled and run	-5
B	Not all the images created as required	-5

## Results

Updated for the “hybrid” situation, ZOOM-based logistics was tested during the last two semesters. By comparing the level of students’ presentations and the complexity of the code with those of “normal” semesters, COVID-19 semesters, and “hybrid” semesters, it can be stated that the level of the presentation and the level of the code were practically identical. However, considering the small number of semesters in each category, it is clear that no valid statistical analysis can be provided in that case.

## Discussion

All modifications of cloud-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 of the report was requested. In order to prevent the unlimited number of “reworks”, the number of reworks was set to 3 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, most of the students quickly understand the meaning of this limitation, and, at the end, most reports have got maximal grades. At every semester, however, a number of students did not send all reports before the deadline, and, in that case, the final laboratory grade was significantly less than maximal.

Unfortunately, collecting students' opinion (students' feedback) about specific courses under COVID-19 restrictions become problematic, as practically, as ideologically – in the end, only a small number of students provided this feedback. Hence, this parameter cannot be used to evaluate the quality of the selected cloud approach. However, privately, after getting final grades, many students claimed that this specific laboratory can be provided by using cloud services.

## Conclusions

Modified logistics of cloud-based image processing laboratory were found to be reasonably time-effective for the educator.

Cloud-based courses have some obvious advantages and some disadvantages. The educator cannot be aware that specific students really executed all laboratory assignments without significant external assistance. It was practically impossible to state 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. More R&D work must be done to arrive to statistically valid conclusions if a remote Image Processing laboratory can be good enough compared with a “regular” in-campus laboratory.

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