Course Outline

Fundamentals of Computer Vision COMP 558

Fall 2020 (Remote Delivery)

Instructor: Professor Michael Langer (email michael.langer@mcgill.ca)

*The T.A.'s are responsible for the assignments, so please do not email them for other info.

1 Overview

This course is an introduction to the field of Computer Vision. It covers many core problems of the field, and methods for solving these problems. The methods will range from classical to modern. The field is huge, and so the course will be very selective. We will take a relatively small number of problems and concentrate on the *fundamentals*: for most of the problems we cover, we will present core ideas rigorously and in detail.

The course will be taught *asynchronously*. The official course schedule for lectures is MW 4:05-5:25. We will use this time slot and other time slots (to be determined) for Zoom discussions and office hours. I do not plan to hold live lectures, excepts for the first lecture where I will use Zoom to introduce the course.

That said, the materials will still follow a lecture schedule and will be released weekly as the semester goes along. The materials will be primarily PDFs and example Matlab code. I may experiment try to provide videos to complement these materials, but we will have to see how that goes; it depends on your interest and participation, on my time constraints, and factors beyond our control.

2 Teaching Assistants (T.A.)

The teaching assistants are:	Manoosh Samiei	email
	Nishant Mishra	email
	Shubham Chopra	email

They will be primarily responsible for handling the assignments, including Zoom office hours and mycourses discussion board before each assignment is due. They will also be responsible for grading the assignments.

3 Course Materials

3.1 Lecture Notes, Slides, and Exercises

The course materials will consist of slides, typeset lecture notes, and Matlab code. All will be made available on mycourses. These materials will be sufficient for studying for the quizzes and final exam, and for doing the assignments.

The main advantage of using slides and notes is that I can easily edit them and repost them. Questions will come up and typos/errors will be pointed out. When this happens, I will do my best to make the corrections or clarifications.

I also plan to make some Exercises for most of the lectures so that you can study and practice the ideas and techniques. I may use these exercises to guide live discussions during Zoom sessions.

By the way, the materials that I post are mine, written from scratch. As such, please respect the McGill Policy on Protected Course Material:

"Instructor generated course materials (e.g., handouts, notes, summaries, exam questions, etc.) are protected by law and may not be copied or distributed in any form or in any medium without explicit permission of the instructor. Note that infringements of copyright can be subject to follow up by the University under the Code of Student Conduct and Disciplinary Procedures."

3.2 Supplementary Materials

Most topics covered in the course are covered in the well-known survey book by Richard Szeliski, which is available as a PDF of the textbook **Computer Vision: Algorithms and Applications**. The book was published in 2010. It gives a very nice survey of the field at that time.

There are many video resources. See the slides of lecture 1 for links to MOOCs, for example.

4 Prerequisites

The following are the McGill courses that I expect you to have taken (or have taken equivalents) before this course:

- data structures and algorithms (COMP 251)
- multivariable calculus (MATH 222)
- linear algebra (MATH 223)

Programming requirements: The COMP 251 prerequisite is perhaps overkill. Although some of the techniques in that course such as dynamic programming and network flows are used often in computer vision, we will likely not use these techniques in COMP 558. So you will be fine with data structures and algorithms at the level of COMP 250, and a solid background in programming.

In particular you should have enough experience that you can basic Matlab on your own to do the assignments.

Math requirements: You are expected to have a solid background in multivariable calculus and linear algebra. For the latter, you should be comfortable with vector spaces and, in particular, properties of matrices such as rank and eigenspaces.

5 Evaluation

5.1 Three Assignments ($12\% + 12\% + 16\% = 40\%$)

The assignments will involve Matlab programming, and possible reading a research paper. If you do not know Matlab prior to the course, then you will need to learn it. There are many tutorials online, and I will give example code for you to work with.

A free Matlab license is available to all McGill students for download. Be sure to include the Image Processing and Computer Vision toolboxes when you download it.

Here is a rough schedule for the three assignments:

- A1 will be posted by September 25; It is worth 12 % of course grade.
- A2 will be posted by October 16; It is worth 12 % of course grade.
- A3 will be posted by November 13. It is worth 16 % of course grade.

You will be given approximately two weeks to do Assignments 1 and 2, and about three weeks for Assignment 3. Extensions will be given only for unforeseen reasons, such as extended illness. In that case, I reserve the right to ask for documentation.

If you don't do an assignment then you get 0.

5.2 Five Quizzes ($0 - 5 \times 5\% = 0 - 25\%$)

We will hold five quizzes on mycourses. The quizzes will be a mix of multiple choice, multisect, and short answer questions. Each quiz will be designed to take no more than one hour. Because of COVID and limited accessibility, the Faculty of Science requires that the quiz will be open for one day (24 hours).[1] If possible, try to complete the quiz early in the day to avoid internet issues.

The quizzes are to be done alone. No correspondence between you and your fellow students about the quiz or any quiz material is allowed on the day of the quiz. On the day of the quiz, any questions about the quiz or material covered by the quiz must be sent by email to me (not to the T.A.'s).

[Sept. 2 update] *Instructors in Faculty of Science have just be told that we cannot ask for medical notes for missed quizzes or midterm exams. Therefore, I have revised the policy for quizzes to be*

[1] Faculty of Science COVID Fall 2020 guidelines.

as follows: If your percentage grade on the final exam exceeds your percentage grade on any quiz, then your quiz grade will be replaced by your final exam (percentage) gradefor that quiz. This policy holds independently for all quizzes.

The quizzes will be held on Mondays or Wednesdays, roughly every two weeks starting September 28. The advantage of using these days is that the course is officially scheduled to be on these days, so there should be fewer conflicts. Planned dates of quizzes and planned lectures covered by each quiz are:

1. Monday, September 28 (lectures 2-5)
2. Wednesday, October 14 (lectures 6-9)
3. Wednesday, October 28 (lectures 10-13)
4. Wednesday, November 11 (lectures 14-17)
5. Monday, November 30 (lectures 18-22)

We reserve the right to change these dates and lectures covered. Such changes would be announced on mycourses.

5.3 Final Exam ($35 - 60\%$)

The Final Exam will be held during Final Examination Period. The exam will consist of multiple choice questions and possibly short answer questions. It will be *open book*. The same policies will hold for the final exam as listed above for the quizzes. The final exam will be designed as a 3 hour exam. You will be given a 72 hour interval to complete it. (See Faculty of Science guidelines in footnote on previous page.)

[**See the Sept. 2 quiz update above.**] Your final exam percentage grade will automatically replace your quiz grade. For example, if you get 70 % on the final exam and you didn't write two quizzes (0%) and your percentage grade on the three quizzes that you did write was 20 %, 60 % and 80 %, then your final exam percentage grade will replace your two 0 grades and your 20 % and 60 % grades, but not your 80 % grade.

McGill policy on the Evaluation scheme

As stated in Article 3.2.3, of the student assessment policy: "*In the event of extraordinary circumstances beyond the University's control, the evaluation scheme in a Course is subject to change, provided that there be timely communications to the students regarding the change.*"

6 Course Topics

6.1 McGill Calendar Course Description

"Image filtering, edge detection, image features and histograms, image segmentation, image motion and tracking, projective geometry, camera calibration, homographies, epipolar geometry and stereo, point clouds and 3D registration. Applications in computer graphics and robotics."

6.2 Detailed list of lecture topics

The course has two parts. The first part addresses 2D image analysis and interpretation. The second part addresss 3D geometry and reconstruction.

- Part 1: 2D Vision
  - RGB
  - Image filtering
  - Edge detection
  - Least Squares Estimation
  - Robust Estimation: Hough transform & RANSAC
  - Features 1: corners
  - Image Registration: the Lucas-Kanade method
  - Scale spaces (Gaussian and Laplacian)
  - Histogram-based Tracking:
  - Features 2: SIFT, HOG
  - Features 3: CNN's
  - Object classification and detection
  - Segmentation
- Part 2: 3D Vision
  - Linear perspective: vanishing points, homogeneous coordinates
  - Cameras 1: extrinsics, intrinsics
  - Least Squares Estimation 2: SVD
  - Cameras 2: calibration
  - Homographies: image stitching, rectification
  - Binocular Stereo: epipolar geometry & correspondence
  - Cameras 2: lighting, material, photography
  - Cameras 3: RGBD, LIDAR, & point clouds

7 Learning Objectives

By the end of this course, you will:

- have a good basic understanding of the theory of image processing used in computer vision, including RGB analysis, edge detection and interest point detection, histogram based methods for image matching and feature representation, and basic CNN architectures. You will also understand the standard mathematical models that relate 3D scenes and 2D images which are used in computer vision, including perspective transformations, homographies, and the fundamental matrix of binocular vision.
- have hands on experience with computational methods, in particular, using Matlab and its Computer Vision Toolbox.
- understand how the field of computer vision has evolved over time, from classical methods that are based on deterministic models (pre-2000's) to more modern methods that are based on big data and probabilities (200x) to current methods that are based on deep neural networks (since 2012).

Although this course will *not* teach machine learning methods or assume that you are familiar with them, we will touch on the basics of how those methods and how they are used in modern approaches to solving core problems such as object and scene recognition and image segmentation.

8 Communication, Interaction, Engagement

8.1 MyCourses Announcements

You are expected to subscribe to mycourses Announcements. If the TAs or I post an announcement, we will assume that you read it in the same day as it is posted.

8.2 Zoom

This course will be taught *asynchronously.* In particular, I do not plan to lecture using Zoom. Instead, I plan to use Zoom for discussion sessions and for office hours. T.A. office hours also will be on Zoom.

At the present time (Sept. 1), I do not want to commit to how exactly we will use Zoom. We expect the usage of Zoom will evolve as the semester goes along, depending on the eventual number of students registered, participation levels, your preferences, and the reliability of the technology.

8.3 Instructor email policy

I try to answer reasonable email requests in a timely way. So please only email me for urgent matters. Examples include:

- personal circumstances such as extended illness that prevent you from completing assignments
- broken links or incorrect or inconsistent information on the mycourses web site.

For all other communications about the course, especially those where it is conceivable that other students have the same question or concern, please use the Discussion Board.

8.4 MyCourses Discussion Board

When posting to the Discussion Board, please obey the following. *Posting that do not conform may be deleted.*

- Choose the appropriate Topic folder.
- Use the search feature to see if your question has been asked before.
- Choose a suitable subject line, so that others know what the posting is about.
- If you have multiple questions that are unrelated, then use multiple postings so that the thread doesn't become a tangled mess.
- Proofread before posting. Take an extra minute to ensure that what you wrote makes sense.

9 Other Policies

9.1 Calculation of final course grade

There are many factors that determine your final grade, including how hard you work, how talented you are in this subject, how much time you devote to the course, what your academic background is, what your health or family situation is, etc. *However, these factors will not be considered when calculating your final course grade. Rather, your grade will be determined entirely by the grading scheme stated earlier.*

Your final course grade will be rounded off to the nearest integer. If one has a grade of 84.4 then it rounds to 84 and one gets an A-, whereas if it is 84.6 then it rounds to 85 and one gets an A. If one's grade is 84.5, it will round it up to 85. The same round off procedure holds for low grades. If one's final course grade is 49.4 then it rounds to 49 which is an F. A very hard line is drawn here. (Note that grad students need a 65 to pass.)

9.2 Regrading

Mistakes can occur when grading assignments. Not surprisingly, requests for re-grading are always in situations in which students feel they received fewer points than deserved, rather than more points than deserved. With that upward tendency in mind, please note that if you wish me or the

TAs to re-grade a question on an exam or assignment, we will do so. However, to avoid upward grade ratcheting, *we reserve the right to re-grade other questions as well.*

9.3 Additional Work

If you receive a grade of D, F or J, you will *not* be given the opportunity to complete additional work to upgrade your grade.

9.4 Collaboration on assignments

We encourage you to discuss the assignment problems with each other, and to help each other out with debugging. We also encourage you to use the mycourses Discussion Boards. *However, there are limits to your collaboration.* You can give hints (and the TAs and I will give hints sometimes if you ask). However, the hints and discussion should not go so far that you are revealing the solutions to each other, and you must never copy code from each other. Any cases of suspected plagiarism will be reported to the Disciplinary Officer in the Student's Faculty. See McGill policy on academic integrity below.

9.5 Supplemental/Deferred Exam

There will be a Supplemental/Deferred Exam exam. It will cover the same material as the Final Exam and will replace only the Final Exam grade.

For information on Supplemental Exams, see
`https://www.mcgill.ca/science/student/general/exams/supplemental`.

9.6 McGill language policy

"*In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.* "

`https://www.mcgill.ca/study/2017-2018/university_regulations_and_resources/undergraduate/gi_lang_policy`

9.7 McGill policy on academic integrity

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offenses under the Code of Student Conduct and Disciplinary Procedures. See `http://www.mcgill.ca/students/srr/honest/` *for more information*

9.8 McGill policy on Students with Disabilities:

"As the instructor of this course, I endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, do not hesitate to discuss them with me and the Office for Students with Disabilities, 514-398-6009."