Course Syllabus

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Civil and Environmental Engineering
University of Waterloo, Canada

CIVE 497 – CIVE 700: Smart Structure Technology

UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING

Last updated: 2021-01-06

Introduction

Chul Min Yeum

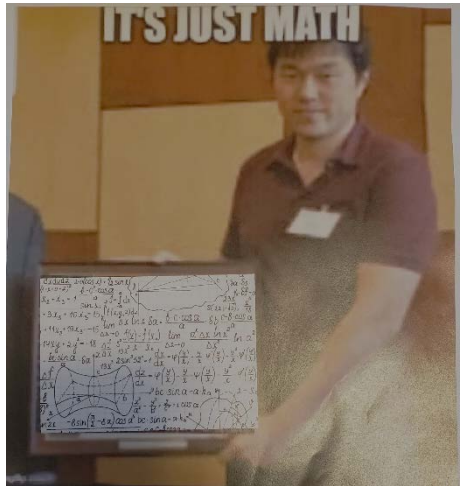
2018 — **Assistant Professor**
Civil Engineering
University of Waterloo, Canada

2016-2018 — **Postdoctoral Research**
Civil Engineering
Purdue University, United States

2012-2016 — **Doctoral Degree**
Civil Engineering
Purdue University, United States

2008-2010 — **Master's Degree**
Civil Engineering
Korea Advanced Institute of Science and Technology, South Korea

2002-2008 — **Bachelor's Degree**
Civil Engineering
Korea Advanced Institute of Science and Technology, South Korea



Experience

Engineer In Training
Konstant · Full-time
Jun 2019 – Sep 2020 · 1 yr 4 mos
Oakville, Ontario, Canada

Engineering Design and Research Assistant
Konstant
May 2017 – Jan 2019 · 1 yr 9 mos
Oakville, ON

Assistant Inspector
City of Brampton
Sep 2016 – Dec 2016 · 4 mos

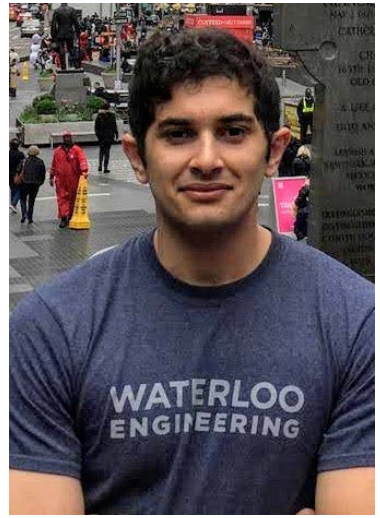
Research Assistant
University of Waterloo
Jan 2016 – Apr 2016 · 4 mos

Research Assistant
University of Waterloo
May 2015 – Aug 2015 · 4 mos

Education

University of Waterloo
Master's of Applied Science, Civil Engineering
2020 – 2022

University of Waterloo
2014 – 2019



Zaid Al-Sabbag

Course Description

This course offers an introduction to the emerging **smart structure technologies** in civil engineering. Smart structures integrate sensing, actuation, data processing, analysis, and visualization, and control capabilities so that a structure can sense and respond to its changing external conditions in a rapid and automated manner. Among several topics in smart structure, this course focuses on using **optical sensor** data by implementing state-of-art image processing and computer vision techniques. As a special topic, basic concepts in **structure from motion**, **machine learning**, and **neural networks** are covered and relevant applications in civil engineering are introduced. An application-based learning approach is emphasized, and tasks are designed in such **a way that students can implement smart structure technology** to address contemporary problems in civil engineering. In addition, for graduate students, students can **opt to** perform a research project, in which students will have an opportunity to design a technique with a potential application to smart structures and advance their research works.

Course Description (Continue)

This course is specially designed to suit the interest of **graduate students** and **senior undergraduate students who may pursue graduate studies**. Based on the feedback received from the courses offered in previous years, you are expected to spend **12 hours or MORE** per week studying class materials as well as working on task assignments and research project.

All lectures and tutorials will be delivered using pre-recorded videos. All videos will be uploaded on a **YouTube Channel**. However, there will have several live help sessions in our class time to review homework problems, homework solutions, and lectures. The live sessions may not be recorded so students are encouraged to attend the live session. (Note if the students cannot attend this live session due to time difference, please inform the instructor at the beginning of this course).

If You Haven't Decide Whether You Take This Course or Not…

- If you are graduate students and interested in this topic, I highly recommend taking this course. This course might provide you a **new perspective on your research development.**

- If you are undergraduate students and keen on taking this course, at least one of following conditions should be applicable to you:
  - I like programming and have a sufficient level of computer programming.
  - I have taken at least one course from the other departments or online sites (e.g., Coursera) that focuses on the following topics: Signal processing, image processing, computer vision or machine learning.
  - I would pursue a graduate study
  - I have plenty of time this term (more than 12 hours/week) and am willing to take a challenging course.

Course Objectives

By the end of this course, students should be able to

- Describe smart structure technology and its applications in civil engineering
- Explain the working principle of an accelerometer and digital camera, and their data acquisition process
- Interpret the concept of image processing techniques through signal processing theory
- Develop programs (MATLAB or Python) to process and analyze 2D and 3D optical data for structural assessment
- Demonstrate how to implement machine learning algorithms in solving real-world problems
- Devise innovative smart structure technology for civil engineering applications and research

Course Outline

Class	Topics	Slides	Tutorial	Load	ETF	Homework
Class 01	Introduction	slide		0.5	Jan 13	
Class 02	MATLAB Tutorial	slide	tutorial	1	Jan 15	Task01
Class 03	Data Acquisition	slide	tutorial	1	Jan 20	
Class 04	Signal Processing I			1	Jan 22	Task02
Class 05	Signal Processing II			1	Jan 27	
Class 06	Signal Processing III			1.5	Jan 29	Task03
Class 07	Digital Image			1	Feb 03	Task04
Class 08	Projective Geometry			3	Feb 12	Task05
Class 09	Linear Filtering			1	Feb 17	
Class 10	Edge Detection			1	Feb 26	
Class 11	Image Thresholding			2	Mar 05	Task06
Class 12	Feature			1.5	Mar 12	
Class 13	RANSAC			1	Mar 17	Task07
Class 14	Camera Model			1	Mar 19	
Class 15	Two-view Geometry			1.5	Mar 24	
Class 16	Structure From Motion			0.5	Mar 26	Task08
Class 17	Introduction of Machine Learning			0.5	Mar 31	
Class 18	Gradient Descent			1	Mar 31	
Class 19	Training Linear Model			1	Apr 02	
Class 20	Neural Network			2	Apr 09	Task09

Introduction

Signal Processing (1D)

Image Processing (2D)

3D Data Processing (3D)

Machine Learning

Prerequisite

This course requires basic knowledge in **linear algebra** and **probability** and skills at ***a sufficient level of a non-trivial computer programming*** (with **MATLAB** or **Python**). Students also need to know how to use **Markdown**. If you are not familiar with or would revisit these topics, students must complete the following tutorials and questions inside:

MATLAB tutorials

- **AE/ENVE/GEOE121: Computational Method**
- **How to download and install MATLAB in your computer?**
- **Matrices & Arrays**: copy this folder in your computer and run `matrices_arrays.mlx` in MATLAB
- **Operations and Elementary Operations**: copy this folder in your computer and run `operators_elem_operations.mlx` in MATLAB

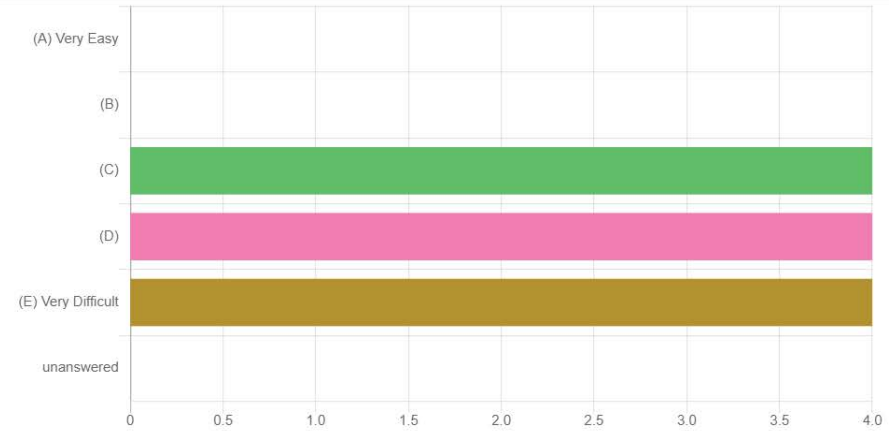
Topics

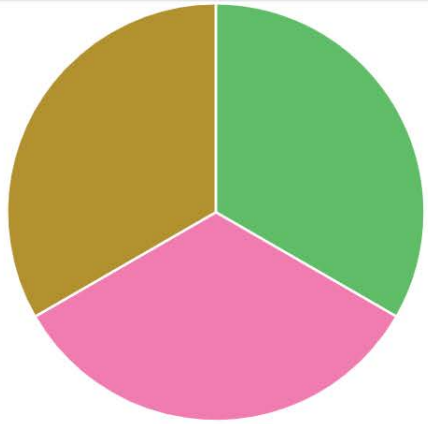
- **Digital Image Processing**: copy this folder in your computer and run `digital_image_processing.mlx` in MATLAB (Note: If you do not find the sample images, you can download them from **here**)
- **Markdown**

Course Evaluation in W20

Q11

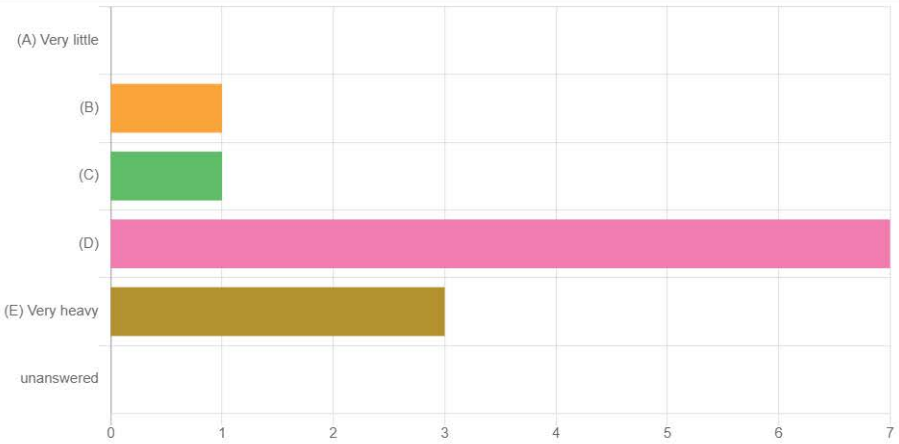
Rate the difficulty of the concepts covered by this course. *Note that (C) is the best rating

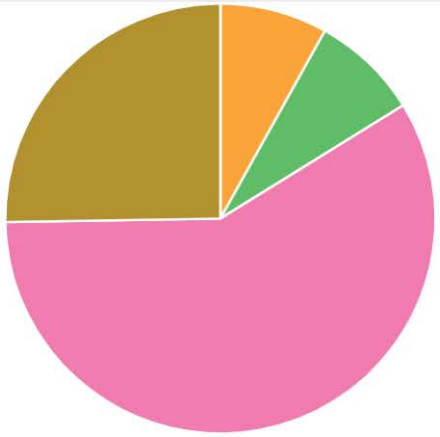




Q12

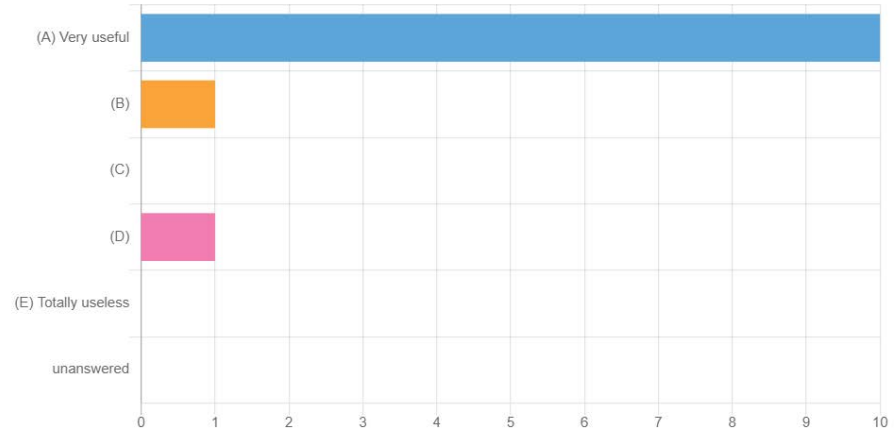
Rate the workload required to complete this course. *Note that (C) is the best rating





Q14

To what extent did the assignments contribute to your better understanding of the concepts.



Grading

The final grade will be based on the total marks earned during the semester. Each task will be graded on the basis of 100 points and will contribute the final grade with **different weights**. Note that undergraduate and graduate students are marked using different evaluation metrics.

If you are a graduate student, you can **opt in** conducting a research project. Students can bring their own problems related to their thesis, research projects or potential research in civil engineering that they plan to pursue near future. This course gives special attention to exploring theory and potential techniques in the field of smart structure to address real problems that students are exposed to or involved in. Thus, students need to devise feasible project topics that are achievable within your current or future graduate study. **For the students who conduct their research projects, the final grade metric becomes Tasks (70%) and Project (30%).**

Project

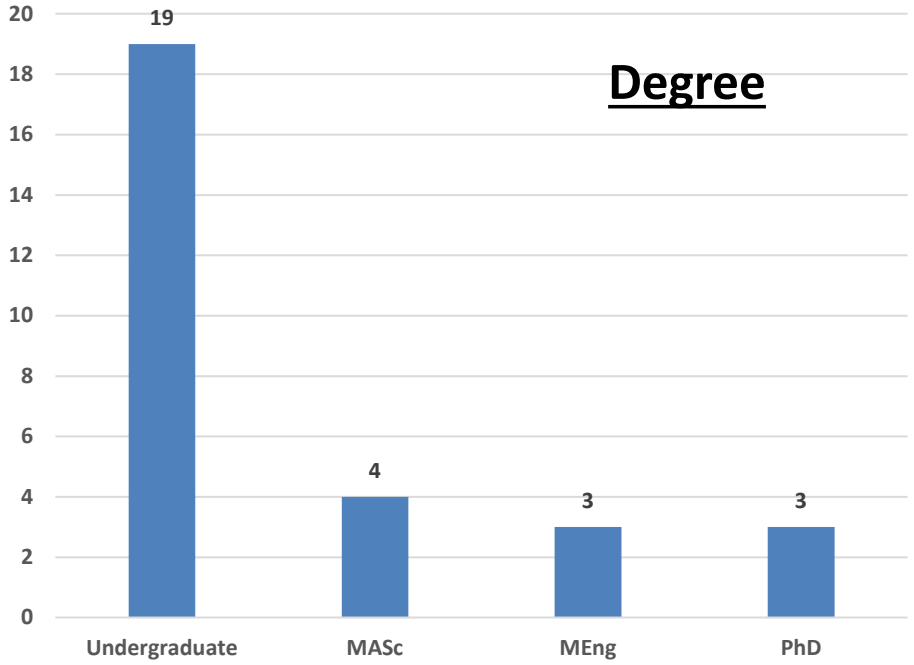
Students are encouraged to **bring their own problems** related to their thesis, research projects or potential research in civil engineering that they plan to pursue near future.

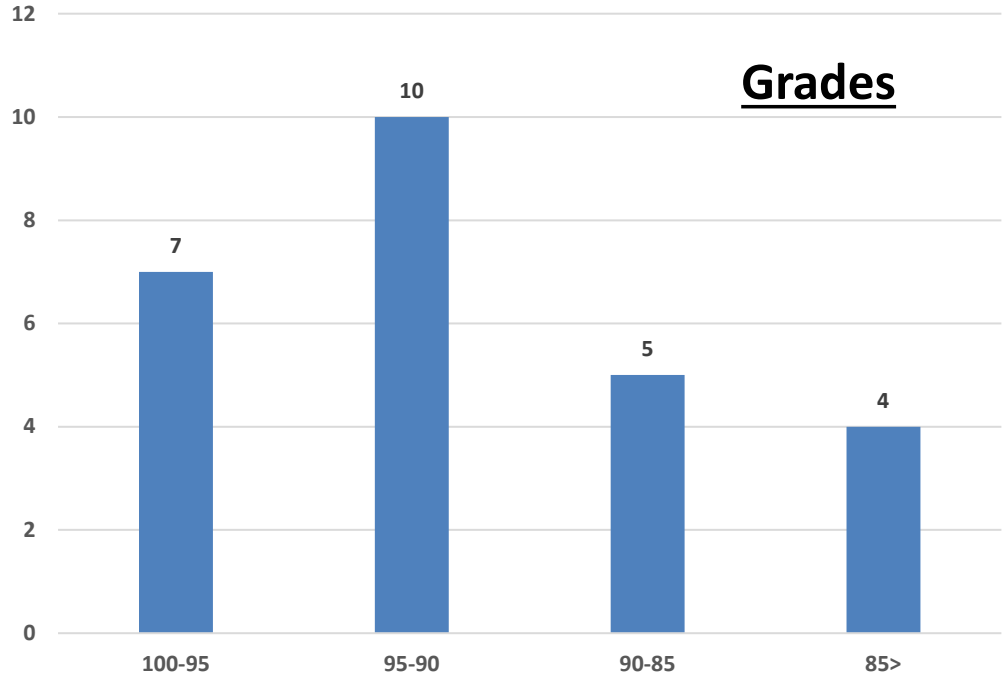
This course gives special attention to exploring theory and potential techniques in the field of smart structure to address real problems that students are exposed to or involved in.

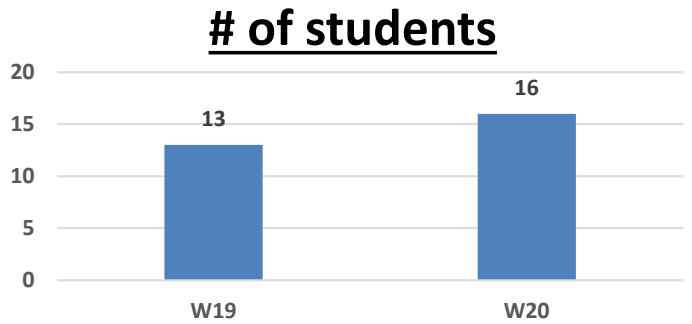
Thus, students need to devise feasible project topics that are achievable within your current or future graduate study.

Tell us what you want to get from this course?

Statistics from the Course in W19-W20





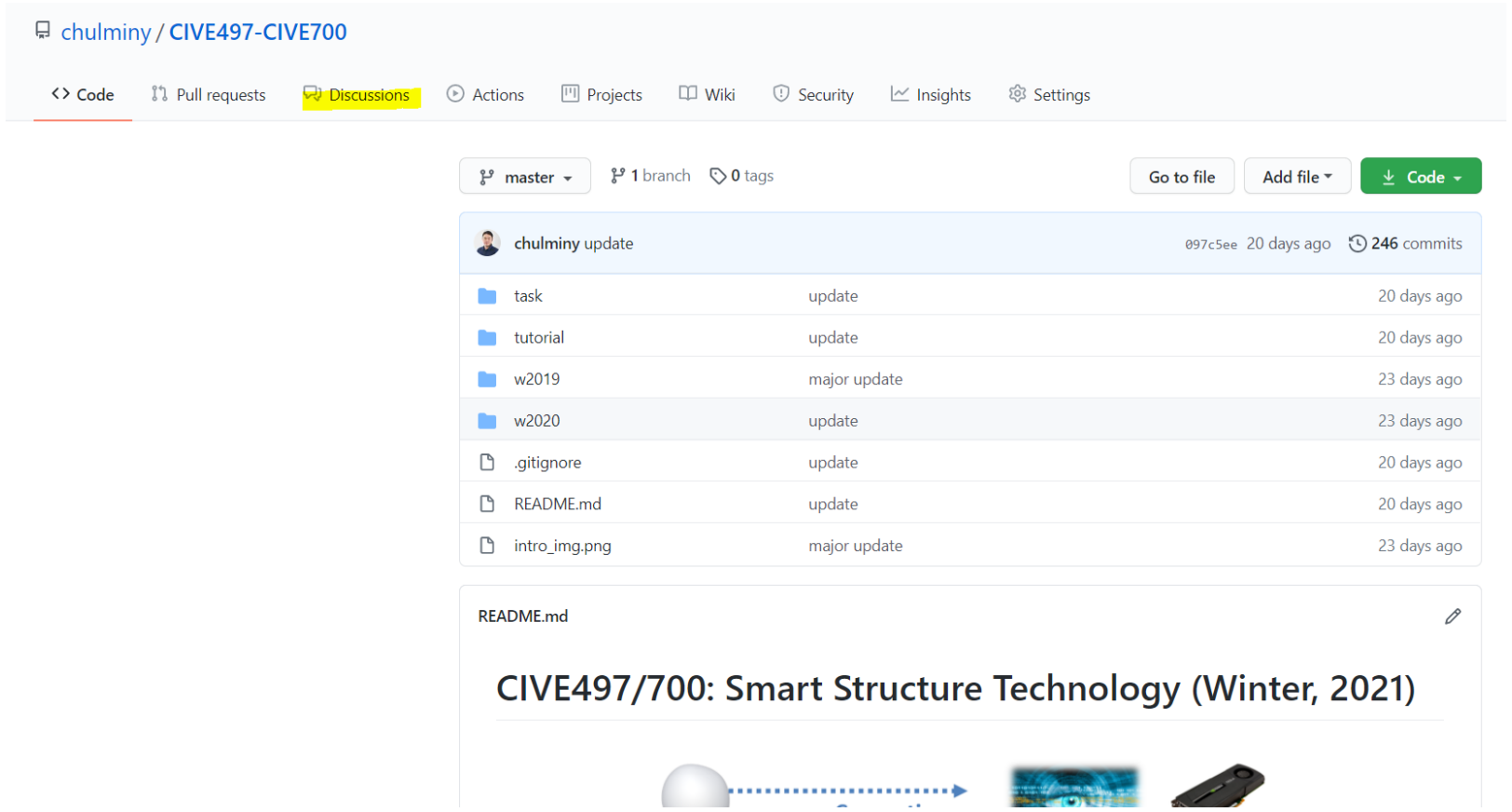


Communication

All communication will be made through this course website, especially for this web page. The instructor will make a note in the "**Announcement**" section if there is an update on the web page. Students can configure email notification for by "watching" this course website or use a version control system for tracking its changes. Thus, **students are responsible for checking the website regularly for any relevant course information or announcements.**

In this course, both the instructor and the students are encouraged to engage in online discussions to create and facilitate a collaborative learning experience. Students are invited to ask questions and answer them, and share their knowledge and resources. Please direct your communication to a Discussion board (tab) on this website. However, if there is a good reason not to use the discussion forum (e.g. personal matters, a question that might reveal your solution of your report, etc.), please directly contact the instructor via email (cmyeum@uwaterloo.ca). Or, you can feel free to send messages the instructor or TA through Microsoft TEAM. You can check out this website. If possible, the instructor and TA prefer to use the discussion forum because questions and responses can be shared to the other students.

Course Website in Github



https://help.github.com/en/github/receiving-notifications-about-activity-on-github/watching-and-unwatching-releases-for-a-repository

https://www.youtube.com/watch?v=77W2JSL7-r8

Tasks

There will be **9 tasks** and they will be posted on this course website weekly or bi-weekly. **The instructor encourages students to work in groups through collaborative learning, but to submit their assignments individually.** The task will have programming components or photography components, where students will use their own camera to capture and process their own images and discuss the results. Students are supposed to complete all tasks and turn their works in by the due date. You can access the best reports for the assignments in previous years from **w2019** and **w2020**. The problems will be similar to the ones in the previous assignments. However, the students must not copy and paste the codes or texts in those reports.

Previous Task Assignment

Task	Topics
Task0	MATLAB and Digital Image Processing Tutorial Best report (Kareem Mostafa)
Task1-1	Signal Processing I Best report (Laurent), Best report (Wildt)
Task2	Camera Sensor Best report (Tianyi), Best report (Juan)
Task1-2	Signal Processing II Best report (Steven)
Task3	Homography Best report (Hongyi)
Task4	Image Filter (No best report)
Task5	Image Stitching Best report (Laurent)
Task6	3D Measurement using SfM
Task7	Scan Registration
Task8	Neural Network

https://github.com/chulminy/CIVE497-CIVE700/tree/master/w2019#tasks

Task	Topics
Task1	Programming Practice
Task2	Signal Processing I Best report (Saeed Ardakani)
Task3	Signal Processing II Best report (Charlotte Mei), Best report (Aleksandar Jakovljevic)
Task4	Digital Image Processing & Camera Sensor and Digital Image Best report (Hana Bregman), Best report (Saeed Ardakani)
Task5	Homography Best report (Armina Soleymani), Best report (Saeed Ardakani)
Task6	Image Filter & Edge Detection Best report (Jasmine Zou), (Aleksandar Jakovljevic), (Saeed Ardakani)
Task7	Image Stitching & RANSAC Best report (Saeed Ardakani)
Task8	Neural Network Best report (Saeed Ardakani)

https://github.com/chulminy/CIVE497-CIVE700/tree/master/w2020#tasks

Late Submission

The late submission policy allows students to have a **maximum one-week** delay for **three among the first eight assignments** (You must submit the last assignment on time). TAs will just count the number of delays in your homework assignments. TAs will inform the students when they delay their submission three times. If the number of delays is more than three, **the fourth delayed homework will be zero.** Students must pay close attention to deadlines. No further late submission will not be accepted unless accompanied by a valid excuse and some marks might be deducted depending upon the circumstances.

When you decide to delay your homework assignments, please carefully consider all schedules and milestones for your other courses. Usually, students get busier when they prepare exams (or quizzes) or the due date for their capstone projects is approaching.

This course grades your final mark based on the marks earned from these assignments. Thus, not submitting homework assignments is a really bad idea and your final score will significantly drop. If you have difficulty in doing the assignments, please speak to the instructor or TA.

Task Assignment List

Task	Topics	Announcement	1st Due	2nd Due
Task01	Programming	Jan 11	Jan 22	Jan 29
Task02	Signal Processing 1	Jan 20	Jan 29	Feb 05
Task03	Signal Processing 2	Jan 27	Feb 10	Feb 17
Task04	Digital Image	Feb 03	Feb 15	Feb 22
Task05	Homography	Feb 10	Feb 24	Mar 03
Task06	Image Processing	Feb 24	Mar 09	Mar 16
Task07	Feature Matching & RANSAC	Mar 09	Mar 22	Mar 29
Task08	Multiview Geometry (SfM)	Mar 19	Apr 02	Apr 09
Task09	Neural Network	Apr 09	Apr 23	Apr 23

Tasks in W19

Hanging a nice picture

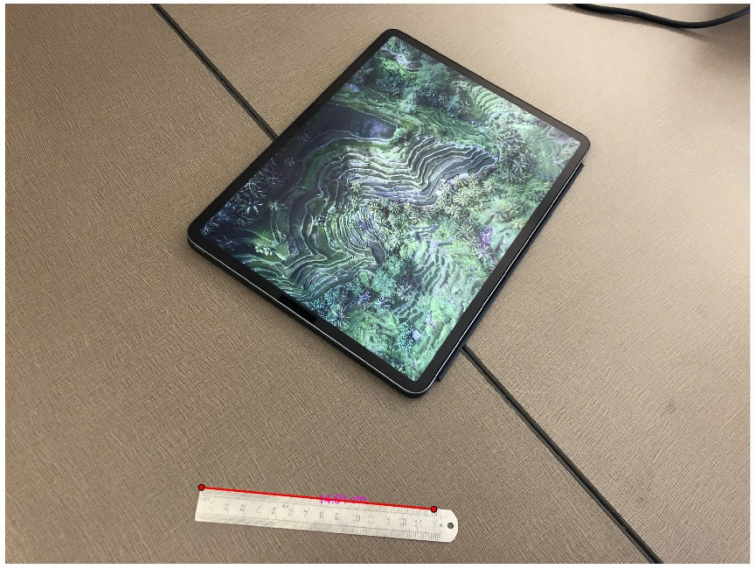
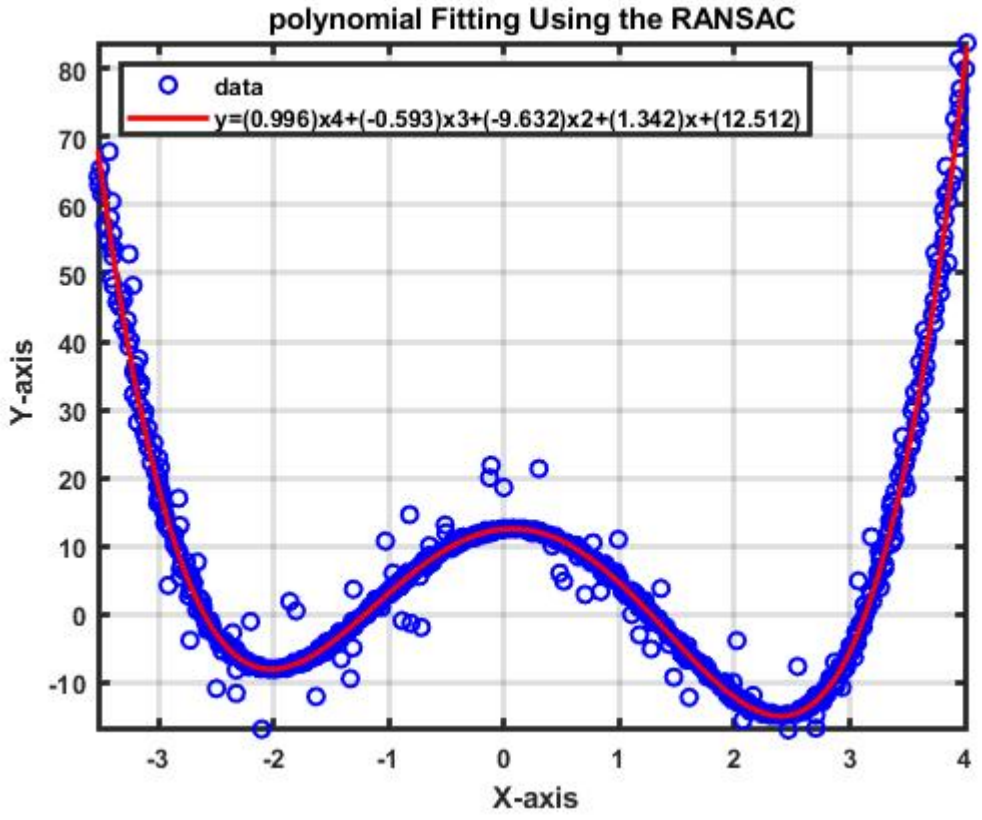


Image-based measurement

Tasks in W19 (Continue)



Polynomial fitting

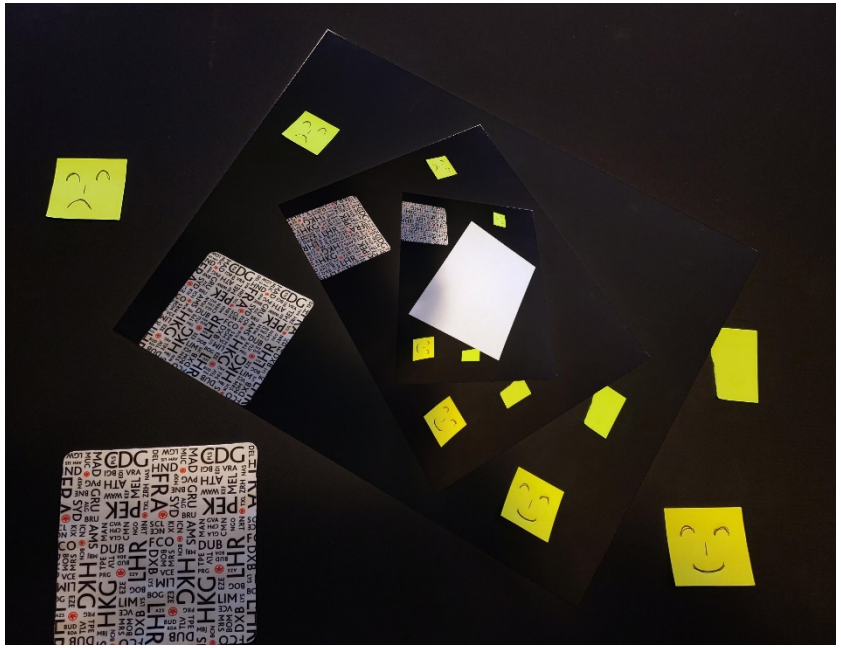
Book detection

Tasks in W20

Image Overlay

Image Stitching

Tasks in W21



Picture in Picture

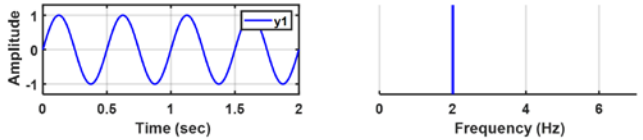
Feature Detection/Matching

Tutorial Code

Continuous Time Signals in a Frequency Domain

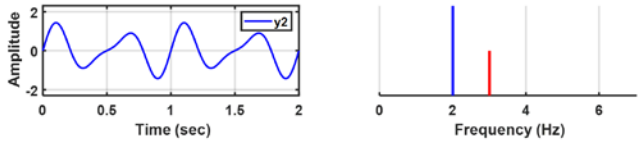
$y_1 = \sin(2\pi f_1 t)$

f_1: 2Hz



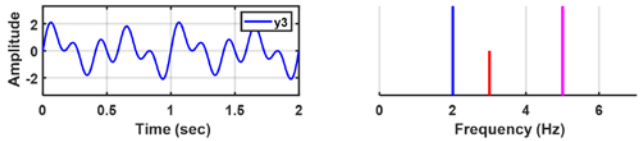
$y_2 = \sin(2\pi f_1 t) + 0.5\sin(2\pi f_1 t)$

f_1: 2Hz, f_2: 3Hz



$y_3 = \sin(2\pi f_1 t) + 0.5\sin(2\pi f_1 t) + \sin(2\pi f_3 t)$

f_1: 2Hz, f_2: 3Hz , f_3: 5Hz



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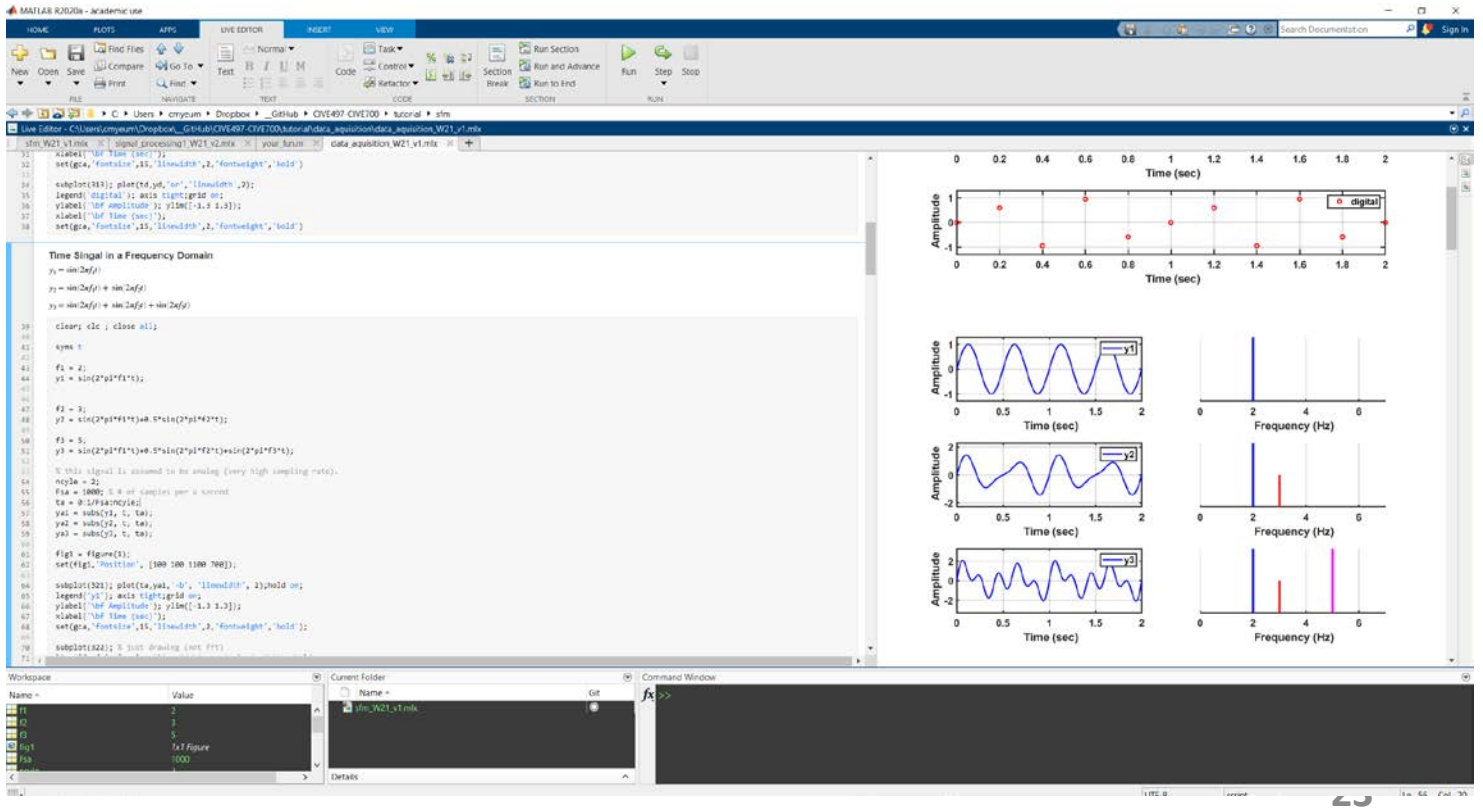
Tutorial

Tutorial codes are very useful to understand the concept as well as doing the task assignments



If there is “tutorial” in the slide, you can see a tutorial code corresponding to the graphs or figures

Some Notes

- I would say this course will be challenging but fun.
- The instructor will do my best to answer your questions and support your study.
- Ask as many questions as you can through the course website or to TA & instructor. It is natural that you do not understand this topic. Don’t be frustrated
- Task assignments are getting challenging.
- You must submit the task assignments (there is no default score).
- Think about how to apply knowledge from the course to your current or future research or job.
- Tutorial are very useful for studying topics.
- Again, this is very tough course. You will spend lots of time to study the topic and do homework.
- Please review the best reports in the previous years. But you should not copy their answers to your report.
- There is no way to adjust a scope of works or topics (schedule) during the term. Thus, you should carefully manage your time to submit your reports.

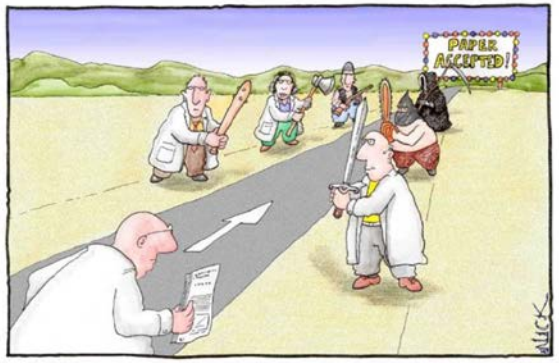
The Most Cited Papers in Computer Vision

COMPUTER VISION, PUBLICATION

The most cited papers in Computer Vision

In Computer Vision, Paper Talk on February 10, 2012 at 11:10 pm

by gooly (Li Yang Ku)



Although it's not always the case that a paper cited more contributes more to the field, a highly cited paper usually indicates that something interesting have been discovered. The following are the papers to my knowledge being cited the most in Computer Vision. (updated on 11/24/2013) If you want your "friend's" paper listed here, just comment below.

Cited by 21528 + 6830 (Object recognition from local scale-invariant features)

Distinctive image features from scale-invariant keypoints

DG Lowe – International journal of computer vision, 2004

Cited by 22181

A threshold selection method from gray-level histograms

N Otsu – Automatica, 1975

Cited by 17671

A theory for multiresolution signal decomposition: The wavelet representation

SG Mallat – Pattern Analysis and Machine Intelligence, IEEE ..., 1989

Cited by 17611

A computational approach to edge detection

J Canny – Pattern Analysis and Machine Intelligence, IEEE ..., 1986

[PDF] **A threshold selection method** from **gray-level histograms**

N Otsu - IEEE transactions on systems, man, and cybernetics, 1979 - cw.felk.cvut.cz

A nonparametric and unsupervised method of automa-tic threshold selection for picture segmentation is presented. An optimal threshold is selected by the discriminant criterion, namely, so as to maximize the separability of the resultant classes in gray levels. The …

☆ 99 Cited by 38527 Related articles All 27 versions »

Random sample consensus: a **paradigm** for **model fitting** with applications to image analysis and automated cartography

MA Fischler, RC Bolles - Readings in computer vision, 1987 - Elsevier

A new paradigm, Random Sample Consensus (RANSAC), for fitting a model to experimental data is introduced, RANSAC is capable of interpreting/smoothing data containing a significant percentage of gross errors, and is thus ideally suited for applications in …

☆ 99 Cited by 23129 Related articles All 7 versions Web of Science: 9962 »

[BOOK] **Multiple view geometry** in **computer vision**

R Hartley, A Zisserman - 2003 - books.google.com

A basic problem in computer vision is to understand the structure of a real world scene given several images of it. Techniques for solving this problem are taken from projective geometry and photogrammetry. Here, the authors cover the geometric principles and their algebraic …

☆ 99 Cited by 26241 Related articles All 29 versions »

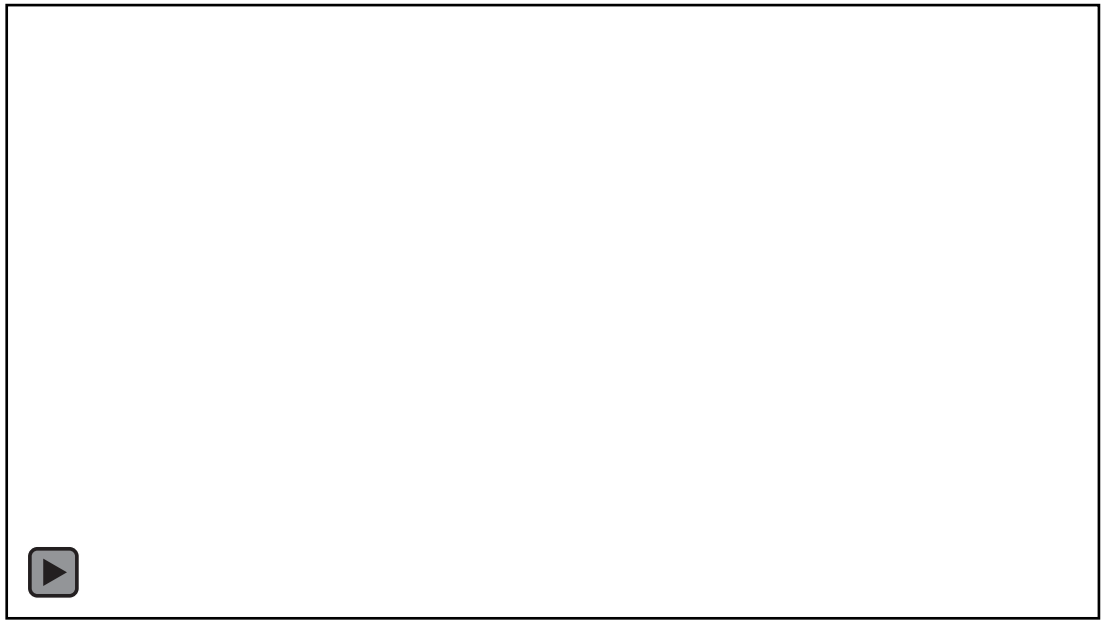
- https://computervisionblog.wordpress.com/2016/06/19/the-most-cited-papers-in-computer-vision-and-deep-learning/
- https://computervisionblog.wordpress.com/2012/02/10/the-most-cited-papers-in-computer-vision/

Remarks

It is not that I’m so smart.

It is just that I stay with problems longer.

- Albert Einstein



https://www.youtube.com/watch?v=G2PJdmG2ICA