CIS 4930.006S20/CIS 6930.013S20: Computational Methods for Imaging and Vision

Spring 2021
Course Information Booklet

The University of South Florida
Department of Computer Science and Engineering
Tampa, FL
January 3, 2021

1 Course Description

Computational imaging systems fully integrate sophisticated computational algorithms into the image-formation pipeline of imaging systems, thus enabling novel imaging systems with capabilities that transcend the limits of conventional imaging systems. In recent years, there has been a rapid growth in the application of computational imaging in consumer photography, microscopy, human computer interaction, autonomous navigation, scientific and biomedical imaging, defense and security, as well as remote sensing. In this course, we will study the computational aspects that form the core of these systems from a signal processing, and inverse problem perspective. We will also explore, recent, exciting examples of computational imaging in action: From 3D imaging with as little as one detected photon per pixel and seeing around corners, to imaging of biological structures previously thought to be unresolvable using light.

Useful information

- **Course credit:** 3
- **Lecture schedule:** *Mondays, 3:30 PM – 4:45 PM* and *Wednesdays, 3:30 PM – 4:45 PM*
- **Meeting Location:** Remote (MS Teams)
- **Delivery Method:** Distance learning

Instructor: John Murray-Bruce

- **Office:** ENG 117A
- **Phone:** (813)-974-3561
- **Email:** `murraybruce@usf.edu` *(Please prepend "[CIS 4390/6390]" to the subject of your email for a timely response.)*
- **Office Hours:** Tuesday 1:00 PM – 2:00 PM, and Wednesday, 5:00 PM – 6:00 PM

Teaching Assistant: Ryan Fogarty

- **Office:** —
- **Email:** `rfogarty@usf.edu`
- **Office Hours:** [TBA]

2 Course Objectives

The main objectives of this course are to develop students':

1. Knowledge of the mathematical foundations of the field of computational imaging.
2. Understanding some limitations of classical imaging modalities.
3. Understanding of the merits and importance of the co-design of imaging systems and algorithms.
4. Understanding of LSI and LSV imaging systems.
5. Understanding of inverse problems.
6. Understand what makes an inverse problems ill-posed or ill-conditioned.
7. Understand how to "cure" ill-conditioning.

3 Student Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Identify inverse problems in imaging.
2. Will be able to formulate computational imaging problems as inverse problems.
3. Identify, implement, and suitably apply inverse algorithms to imaging problems.
4. Read, assimilate and explain recent publications in the area of computational imaging to their peers.
5. Correctly define and identify ill-posed and ill-conditioned inverse problems.
6. Correctly define regularization and apply it to computational imaging problems.

4 Course Pre-requisites

- COP 4530 (Data Structures), and
- CDA 3201 (Program Design).

This means that you will have taken Calculus I and II (MAC 2281/2282/2312) or equivalent, as well as General Physics I and II (PHY 2048/2049) or equivalent. Thus, you'll have some knowledge of Multivariable calculus, Linear Algebra and Probability. Knowledge of Fourier Transforms, Convolution and Convex Optimization is useful, but is not assumed.

5 Required Texts, Supplementary Materials, and Useful Readings

Main text

- **[IIP]** M. Bertero and P. Boccacci, "Introduction to Inverse Problems in Imaging," Taylor and Francis. 1998, ISBN 9780750304351.

Suggested readings

- **[SMIV]** Julien Mairal, Francis Bach, and Jean Ponce, Sparse Modeling for Image and Vision Processing, NOW 2014. http://lear.inrialpes.fr/people/mairal/resources/pdf/review_sparse_arxiv.pdf
- **[FSP]** Martin Vetterli, Jelena Kovačević, and Vivek Goyal, Foundations of Signal Processing, Cambridge University Press 2014. http://fourierandwavelets.org/

6 Tentative Syllabus

Subject to change.

Week	Date	Main Topic	Lecture	Readings	Homework	
					Out	Due
1	11-Jan-21		Introduction to computational imaging - Forward and Inverse problems - Common computational imaging problems			
	13-Jan-21		Vectors - Preliminaries			
2	18-Jan-21		**Dr. Martin Luther King, Jr. Holiday (no class)**			
	20-Jan-21	Mathematical preliminaries	Vectors and Vector Spaces - Subspaces, Finite dimensional spaces	IIP Appendix A; FSP 2.1 - 2.2		
3	25-Jan-21		Vector Spaces - Hilbert spaces	IIP Appendix B; FSP 2.3		
	27-Jan-21		Bases and Frames I - Orthonormal and Reisz Bases	IIP Appendix C; FSP 2.4 and 2.B	**HW 1**	
4	1-Feb-21		Bases and Frames II - Orthogonal Bases - Linear operators	IIP Appendix C; FSP 2.5 and 2.B		
	3-Feb-21		Fourier Analysis I - FT (1D and 2D) - FT properties	IIP 2.1, Appendix D; FSP 4.4		
5	8-Feb-21		Sampling and Interpolation - BL functions - Sampling	IIP 2.2, 2.3; FSP 5.4, 5.5		**HW 1**
	10-Feb-21		Fourier Analysis II (DFT)	IIP 2.4; FSP 3.6	**HW 2**	
6	15-Feb-21	Forward Modeling	LSI imaging: Forward problem I - Convolution	IIP 2.5 - 2.6, 3		
	17-Feb-21		LSI imaging: Forward problem I - Transfer functions	IIP 2.6		
7	22-Feb-21		LSI imaging: Forward problem I - Linear operators	IIP 3		
	24-Feb-21		LSI imaging: Forward problem I - Linear operators, Adjoints, and Inverses		**HW 3**	**HW 2**
8	1-Mar-21		**Mid-term Exams**			
	3-Mar-21		LSI imaging: Forward problem II - Sampling and Discretization: Matrix-vector form	IIP 2.7, 4		
9	8-Mar-21		LSI imaging: Forward problem II - Convolution matrix			
	10-Mar-21		LSI imaging: Forward problem II - Sampling and Discretization: Matrix-vector form - PSF, and Transfer functions			**HW3**

10	15-Mar-21	Forward Models and Inverse Problems	Linear Inversion - Inverse problems - Deconvolution and Denoising	IIP 4, Appendix E	**HW 4**	
	17-Mar-21		Intro to Regularized Inversion I - Tikhonov	IIP 5, Appendix E		
11	22-Mar-21	Regularization	Intro to Regularized Inversion II - Iterative methods - Steepest descent	IIP 6		
	24-Mar-21		Statistical methods I - ML estimation - Bayesian estimation	IIP 7.1 - 7.5		
12	29-Mar-21	Forward models and Inverse Problems II	LSV imaging systems: Forward problem - SVD - Inversion	IIP 8.1, 9, 10		
	31-Mar-21	Non-linear Regularization	Beyond L_2-regularization - Sparsity (l_0- and l_1-priors) - TV prior	SMIV 1.1 - 1.5 Papers & Handout		**HW 4**
13	5-Apr-21		Algorithms overview - ISTA/FISTA - ADMM	Papers & Handout		
	7-Apr-21	Introductory Optics	Geometrical/Ray Optics - Rays & pinhole cameras - Lenless imaging and Coded apertures	IIP 8.2, 8.3, 9.5 Papers & Handout		
14	12-Apr-21 14-Apr-21	**Spring Break (no classes)**				
15	19-Apr-21	Applications of Comp. Imaging	Looking around corners (NLOS imaging)	Papers & Handout		
	21-Apr-21		Compressive Imaging and Imaging from few photons	Papers & Handout		
16	26-Apr-21 28-Apr-21	**Group Presentations (Teams)**				
17	3-May-21	***no class**				
	5-May-21	**Final Exam: 12:30 PM - 2:30 PM**				

7 Assessments and Grading

Assessment components.

Assessment component	Percentage of final grade [%]
Homework (4 sets[†])	30%
Mid-term Exam	20%
Project	20%
Final Exam	20%
Participation	10%

[†]The best **three out of the four** homework assignments will be aggregated.

Grade boundaries. The following grade boundaries will be applied:

Grading scale [%]	
93 –	A
[90, 93)	A-
[87, 90)	B+
[83, 87)	B
[80, 83)	B-
[70, 80)	C
[60, 70)	D
[0, 60)	F

Where x in the interval $[a, b)$ means that $a \leq x < b$.

8 Course Policies

Extra credit. In this course, there will be a couple of opportunities to earn extra credit, for specific homework assignments and projects. When extra credits are on offer, concrete guidelines are provided on how they may be earned. However, all decisions on extra credit are made by the instructor, and are considered final: They cannot be appealed/disputed.

Late submission. Late submissions will incur a penalty of 20% per day.

Grades of "Incomplete". Current university policy concerning incomplete grades will be enforced in this course.
For USF Tampa undergraduate courses and USFSM undergraduate and graduate courses: An "I" grade may be awarded to a student only when a small portion of the student's work is incomplete and only when the student is otherwise earning a passing grade. The time limit for removing the "I" is to be set by the instructor of the course. For undergraduate students, this time limit may not exceed two academic semesters, whether or not the student is in residence, and/or graduation, whichever comes first. For graduate students, this time limit may not exceed one academic semester. "I" grades not removed by the end of the time limit will be changed to "IF" or "IU," whichever is appropriate.
For USF Tampa graduate courses and USFSP undergraduate and graduate courses: An Incomplete grade ("I") is exceptional and granted at the instructor's discretion only when students are unable to complete course requirements due to illness or other circumstances beyond their control. The course instructor and student must complete and sign the "I" Grade Contract Form that describes the work to be completed, the date it is due, and the grade the student would earn factoring in a zero for all incomplete assignments. The due date can be negotiated and extended by student/instructor as long as it does not exceed two semesters for undergraduate courses and one semester for graduate courses from the original date grades were due for that course. An "I" grade not cleared within the two semesters for undergraduate courses and one semester for graduate courses (including summer semester) will revert to the grade noted on the contract.

Group work and collaboration. Collaboration, in homework assignments and projects, is permitted and even encouraged in this course. However, if there is collaboration, it must be explicitly acknowledged, and each collaborator must turn in their own individual analysis/code and description of results.

Make-up examinations. If a student cannot be present for an examination for a valid reason (validity to be determined by the instructor), a make-up exam will be given only if the student has notified the instructor in advance that they cannot be present for the exam. Make-up exams are given at the convenience of the instructor.

9 Technology and Media

Canvas. USF's learning management system (LMS), called Canvas, accessible via: www.learn.usf.edu will contain a wealth of course materials — such as, lecture notes/slides, papers, links and so on — so please be sure to If you need help learning how to perform various tasks related to this course or other courses being offered in Canvas, please consult the following Canvas help guides:

- https://guides.instructure.com/m/4212, and
- https://community.canvaslms.com/docs/DOC-10701-canvas-student-guide-table-of-contents.

You may also contact USF's IT department at (813) 974-1222 or help@usf.edu.

Proctorio. All students must review the syllabus and the requirements including the online terms and video testing requirements to determine if they wish to remain in the course. Enrollment in the course is an agreement to abide by and accept all terms. Any student may elect to drop or withdraw from this course before the end of the drop/add period. Online exams and quizzes within this course may require online proctoring. Therefore, students will be required to have a webcam (USB or internal) with a microphone when taking an exam or quiz. Students understand that this remote recording device is purchased and controlled by the student and that recordings from any private residence must be done with the permission of any person residing in the residence. To avoid any concerns in this regard, students should select private spaces for the testing. The University library and other academic sites at the University offer secure private settings for recordings and students with concerns may discuss location of an appropriate space for the recordings with their instructor or advisor. Students must ensure that any recordings do not invade any third-party privacy rights and accept all responsibility and liability for violations of any third-party privacy concerns. Setup information will be provided prior to taking the proctored exam. For additional information about online proctoring you can visit the online proctoring student FAQ at http://www.usf.edu/innovative-education/resources/student-services/online-proctoring.aspx

Recording lectures. Audio and/or video recording of lectures is strictly prohibited.

Recording during live remote lectures. In this class, software will be used to record live class lectures and discussions. As a student in this class, your participation in live class discussions will be recorded. These recordings will be made available only to students enrolled in the class, to assist those who cannot attend the live session or to serve as a resource for those who would like to review content that was presented. Students who prefer to participate via audio only will be allowed to disable their video camera so only audio will be captured. Please discuss this option with your instructor.

10 Student Expectations

Disability Access. Students in need of academic accommodations for a disability may consult with Students with Disabilities Services to arrange appropriate accommodations. Students are required to give reasonable notice prior to requesting an accommodation.

Sexual Misconduct/Sexual Harassment Reporting. USF is committed to providing an environment free from sex discrimination, including sexual harassment and sexual violence (USF System Policy 0-004). The USF Center for Victim Advocacy and Violence Prevention is a confidential resource where you can talk about incidents of sexual harassment and gender-based crimes including sexual assault, stalking, and domestic/relationship violence. This confidential resource can help you without having to report your situation to either the Office of Student Rights and Responsibilities (OSSR) or the Office of Diversity, Inclusion, and Equal Opportunity (DIEO), unless you request that they make a report. Please be aware that in compliance with Title IX and under the USF System Policy, educators must report incidents of sexual harassment and gender-based crimes including sexual assault, stalking, and domestic/relationship violence. If you disclose any of these situations in class, in papers, or to me personally, I am required

to report it to OSSR or DIEO for investigation. Please contact the USF Center for Victim Advocacy and Violence Prevention: (813) 974-5757.

Attendance. Active attendance is strongly encouraged. A small, but non-trivial, portion of your final grade is attributed to class participation. Obviously, you cannot participate in class if you're consistently absent.

Professionalism. Per university policy and classroom etiquette; **mobile phones, iPods, etc. must be silenced** during all classroom and lab lectures. Those not heeding this rule will be asked to leave the classroom/lab immediately, in order to minimize disruption to the learning environment. Please arrive on time for all class meetings. Those found guilty, after prior warnings, of perpetually disrupting class may suffer a reduction in their final class grade. An excerpt from the USF System Regulation 3.025:

> *"Disruptive students in the academic setting severely hinder the [learning] process. Disruption of the academic process is defined as the act, words, or general conduct of a student in a classroom or other academic environment which in the reasonable estimation of the instructor: (a) directs attention away from the academic matters at hand, such as noisy distractions, persistent, disrespectful or abusive interruption of lecture, exam, academic discussion, or general University operations, or (b) presents a danger to the health, safety, or wellbeing of self or other persons. Such disruptions will not be tolerated."*

Academic conduct. Academic dishonesty in any form will not be tolerated. If you are uncertain as to what constitutes academic dishonesty, please consult the University of South Florida's Student Handbook. Violations of these rules will, at best, result in a record of the infraction being placed in your file, along with a zero on the piece of work in question. At the instructor's discretion, you may also receive a failing grade — F, or even FF — for the course. Confirmation of such incidents can also result in expulsion from the University.

Turnitin.com. In this course we will utilize turnitin.com, an automated system which instructors can use to quickly and easily compare each student's assignment with billions of web sites, as well as an enormous database of student papers that grows with each submission. After the assignment is processed, I, the instructor will receive a report from turnitin.com that states if and how another author's work was used in the assignment. For a more detailed look at this process visit `http://www.turnitin.com`.

End of Semester Student Evaluations. All classes at USF make use of an online system for students to provide feedback to the University regarding the course. These surveys will be made available at the end of the semester, and the University will notify you by email when the response window opens. Your participation is highly encouraged and valued. The results of student feedback are sent to departments and faculty members only after semester grades are already submitted, and *student responses are reported only anonymously* and in the aggregate to faculty.

University Writing Center. USF's University Writing Center (UWC) is a free resource for USF undergraduates and graduates. At the UWC, a trained writing consultant will work individually with you on anything you're writing (in or out of class), at any point in the writing process from brainstorming to editing. Appointments are recommended, but not required. For more information or to make an appointment, visit the UWC website at `http://www.lib.usf.edu/writing`, stop by LIB-125, or call 813.974.8293.

Campus Emergencies and Academic Continuity. In the event of an emergency, it may be necessary for USF to suspend normal operations. During this time, USF may opt to continue delivery of instruction through methods that include but are not limited to Canvas and email messaging and/or an alternate schedule. It's the responsibility of the student to monitor the Canvas site for each class for course specific communication, and the main USF, College, and department websites, emails, and MoBull messages for important general information.

11 USF Core Policies

Current policies about accessibility, religious observances, academic grievances, academic misconduct, and several other topics are governed by a central set of policies, which apply to all classes at USF: https://www.usf.edu/provost/faculty/core-syllabus-policy-statements.aspx

Important Dates to Remember.

- **Drop/Add Deadline:** January 15, 2021
- **Dr. Martin Luther King Jr. Holiday (no class):** January 18, 2021
- **Mid – Term Examination:** March 1, 2021
- **Withdrawal Deadline:** March 27, 2021
- **Spring Break:** April 12 – April 18, 2021
- **Final Examination:** May 5, 2021 (Time: 12:30pm – 2:30pm)