CAP 6415 Computer Vision
CRN 86769, 85891, Sections 700 and 701, 3 Credit Hours
COURSE SYLLABUS

Semester: Fall 2023
Dates: 08/21/2023- 12/07/2023
Delivery method: online
Instructor: Sudeep Sarkar (sarkar@usf.edu)
Virtual Office Hours:
Tuesdays and Thursdays, 11 am to 12:15 pm; to contact, send chat to sarkar@usf.edu on MS Teams, and I will call you back on MS Teams.

TA: TBD
Office hours: TBD -- on MS Teams (virtual)

Minimum Technical Skills & Requirements:

You should be familiar with programming with Python. The course will also draw heavily from your knowledge of **data structures, linear algebra, vector calculus, and probability theory**. So, please refresh them during the first week so that you can follow the lectures. Refreshers for these materials are also available in the Appendix of your textbook (free) and as background material on Canvas.

I. **Welcome!**
    We rely on our eyes to survive in this world. You are using it now as you read this text. Your eyes are just registering the color and intensity changes on the retina and sending it off to the brain for further processing to make sense of the registered input. Your perception of this page and the world is relatively stable despite head movements and eye blinks. Ever wonder how all of this happens? Suppose we could replicate even a fraction of this functionality in artificial systems. In that case, we could impact lives through autonomous driving, precise medical diagnosis, computational photographic art, fast and accurate response during disasters, empowerment of the visually disabled, seamless communication with the Deaf, and more.

    Can we write computer algorithms that process information to extract information from images and video? If we and many animal species can do it so effortlessly, how hard can it be? Let us find out.

II.   **University Course Description**

Techniques for description and recognition of objects, use of stereo, texture, and motion information for scene segmentation and description, consistent labeling and matching, use of knowledge and planning in computer vision.

III.   **Official Course Prerequisites (waived)**
        CAP 5400 Digital Image Processing or equivalent experience

IV.   **Course Purpose**
        This is a graduate elective course in the general theme of artificial intelligence (AI) and will teach you about algorithms to extract information from images and video. We will learn about the problems of segmentation, tracking, extraction of geometric transforms in images, estimation of 3D information from a 2D image(s), and object detection and recognition using traditional and deep learning methods.

V.   **Instructor Contact Information and Communication**
        You may address me as Prof. Sarkar. If you would like to consult with me aside from office hours, please send me an email (via Canvas) requesting an appointment. If you think the issue can be resolved via email, please email me. I will try my best to respond within 24 hours.

VI.   **First-Day Attendance Policy**
        There will be a first-day activity that has to be completed and submitted via Canvas by the end of the first day.   Students who don't complete the first-day activity risk being dropped from the course.

VII.   **How to Succeed in this Course**
        You should be familiar with programming with Python. The course will also draw heavily from your data structures, linear algebra, calculus, and probability theory knowledge. So, please refresh them during the first week so that you can follow the lectures. The lectures will involve working through algebraic formulae and geometric reasoning.

        There will be heavy demand on your time beyond the classroom. **Assume you should spend 6 hours every week reading, studying, and doing homework beyond the time spent in class**. You will need to be programming almost every week for this course. Lecture attendance is not required but highly recommended.

1. This one-page handout details what the study skills behaviors of top students look like: http://bit.ly/successfulstudentbehaviors

2. This 18-page PDF provides 101 individual tips for practical study skills and note-taking: http://bit.ly/studyskillstips

VIII. **Course Structure**

This course will be taught in an online manner. You are expected to complete weekly assignments and stay on pace.

The course is divided into 9 modules. Each module covers a topic area in class sessions. Two class sessions constitute a week. Each module typically spans one to two weeks.

Each class session will have reading materials for you to study and assignments to submit on Canvas. The assignments will involve running some variation of a code or solving some math problem, or providing explanations.

IX. **Course Objectives**

- Solve the core problems in computer vision, including segmentation, low-level features, tracking, 2D and 3D image geometry, structure from motion, stereo, and object recognition.
- Use traditional approaches and new deep learning-based solutions to solve computer vision problems.
- Apply the theoretical pinning of the major solution approaches
- Write computer programs based on this understanding to solve real-life problems.

X. **Student Learning Outcomes**
By the end of this course, students will be able to:
- Identify and apply various computer vision methods to images and videos
- Read, understand, and implements ideas in computer vision.
- Code computer vision algorithms based on algorithms specified at a high level.
- Communicate computer vision concepts to others.

XI. **Required Texts and/or Readings and Course Materials**

Computer Vision: Algorithms and Applications, Richard Szeliski, ISBN 978-3030343712, Springer (second edition)

The pdf of the book (Current draft, second edition) is available at http://szeliski.org/Book for free for personal use. You can buy a hard copy, but it is not required.

XII. **Supplementary (Optional) Texts and Materials**

- Nalwa, Vishvjit (1993) A Guided Tour of Computer Vision, Addison-Wesley, Reading MA (ISBN 1-201-54853-4).

- Jain, Ramesh, Rangachar Kasturi, and Brian G. Schunck (1995), Machine Vision, McGraw-Hill, New York (ISBN 0-07-032018-7).

XIII. **Grading Scale**

> 90 to 100: A
> 75 to 90: B
> 60 to 75: C
> 50 to 60: D
> < 50: F

XIV. **Grade Categories and Weights**

There is continuous evaluation in this course. You will be graded based on the quizzes and assignments associated with each class session. **There are no exams or projects**.

Quizzes and assignments for each class session are worth 5 or 10 pts. There are 27 class sessions. The total points earned will be scaled to a percentage, which we will then use to assign letter grades.

XV. **Quizzes and Assignments**

> Quizzes for each class session must be completed on Canvas. You will have only one try. There is no time limit for each question.
>
> Assignments for each class session will consist of analysis and/or programming components. These assignments must be submitted on Canvas. The analysis part needs to be submitted as a pdf document, and the programming part as a Google Colab workbook.
>
> Solutions to your programming assignments must be self-sufficient, and the code implementing the core assignment task should be your own. You cannot use code written by others to construct your solution.
>
> You may use existing packages for file I/O, display graphics, or mathematics packages, such as linear algebra, graphs, and optimization, found in NumPy, PyTorch, etc.

XVI. **Instructor Feedback Policy & Grade Dissemination**

> The teaching team (instructor and/or TA) will make every effort to provide feedback on programing assignments within two weeks of the posted deadline, and feedback on homework within one weeks of the posted deadline. Submissions will be graded online. You can access your scores at any time using "Grades" in Canvas.

XVII. **Course Schedule (**==Note: The Schedule is subject to revision==**)**

Module 1: Image operations (Chapters 2 and 3)
Module 1.1: Overview of computer vision
Module 1.1: OpenCV, CoLab, Numpy, Scikit-image, Matplot,
Module 1.1: Digital camera (Section 2.3), Images and videos as arrays, image thresholding (text separation, text scanning apps)
Module 1.2: Geometric primitives and transformations: 2D transformations (Section 2.1)
Module 1.3: Pixel operations and histogram equalization (Section 3.1)
Module 2: Perspective Camera Model (Chapters 2)
Module 2.1: Perspective camera, intrinsic and extrinsic, 3D rigid (Section 2.1)
Module 2.2: Perspective camera, intrinsic and extrinsic, 3D rigid (Section 2.1)
Module 3: Linear filtering (Chapters 3)
Module 3.1: Linear filtering, Gaussian convolutions, and its derivatives (Section 3.2)
Module 3.2: Linear filtering, Gaussian convolutions, and its derivatives (Section 3.2)
Module 3.3: Linear filtering, Gaussian convolutions, and its derivatives (Section 3.2)
Module 4: Point features and matching (Chapters 3)
Lecture 4.1: Multiresolution representations (image pyramids) (Section 3.5)
Lecture 4.2: SIFT feature detector and descriptor (Section 7.1)
Lecture 4.3: Feature matching, Hungarian, kinds of errors, ROC curves (Section 7.1.3)
Lecture 4.4: Estimating 2D to 2D matching
Module 5: Object labeling using Deep Learning (Chapters 5 and 6)
Lecture 5.1: Deep Learning Networks basics – Single layer network with regression (Section 5.3)
Lecture 5.2: Multilayer Perceptron (MLP) (Section 5.3)
Lecture 5.3: Convolution Neural Networks: Le-Net (MLP)
Lecture 5.4: Convolution Neural Networks: Alex Net (Section 5.4)
Lecture 5.5: Convolution Neural Networks: VGG, ResNet (Section 5.4)
Module 6: Object localization using Deep Learning (Chapters 5 and 6)
Lecture 6.1: Object Detection (SSD) (Section 6.3, 6.4)
Lecture 6.2: Region-based CNNs, R-CNN, Fast R-CNN, Faster R-CNN, Mask R-CNN (Section 6.4)
Lecture 6.3: Semantic Segmentation – Fully Convolutional Networks (FCN) (Section 6.4)
Module 7: 2D to 3D pose alignment
Lecture 7.1: 2D to 3D pose alignment, camera calibration (Section 11.2.1)

Lecture 7.2: 2D to 3D pose alignment, camera calibration (Section 11.2.2)
Module 8: 3D from 2D
Lecture 8:1: 3D from 2D – 2-camera, known geometry, stereo (Section 12.1, 12.3)
Lecture 8.2: 3D from 2D - multi-camera, known geometry, triangulation (Section 11.2.4)
Lecture 8.3: 3D from 2D - multi-camera, known geometry, triangulation (Section 11.2.4)
Lecture 8.4: 3D from 2D – 2-frame, unknown geometry (motion) (Section 11.3)
Module 9: Video processing
Lecture 9.1: Object tracking (Kalman)
Lecture 9.2: Object tracking (Kalman)

* Note: The Schedule is subject to revision

XVIII. **USF Core Syllabus Policies**

USF has a set of central policies related to student recording class sessions, academic integrity and grievances, student accessibility services, academic disruption, religious observances, academic continuity, food insecurity, and sexual harassment that **apply to all courses at USF**. These may be accessed on the USF Core Syllabus Policy Statements page at https://www.usf.edu/provost/faculty/core-syllabus-policy-statements.aspx.

Academic integrity is taken very seriously at USF and in the CSE graduate program. In addition to USF regulations, CSE has the following specific policies. The student will receive a warning letter from the department on the first offense. On the second offense, the student will be immediately expelled from the graduate program. In severe cases, a student may be expelled on the first offense.
For further information, see USF regulation 3.027 on ethics and academic integrity:
https://www.usf.edu/undergrad/students/ethics-integrity.aspx
https://www.usf.edu/graduate-studies/students/academic-integrity-of-students/

XIX. **Student Recordings**

Without prior notice, students may record video or audio of a class lecture for a class in which they are enrolled **for their own personal, educational use**. A class lecture is a formal or methodical oral presentation as part of a university course intended to present information or teach enrolled students about a particular subject. Recording class activities other than class lectures, including but not limited to lab sessions, student presentations (whether individually or part of a group), class discussion, clinical presentations such as patient history, academic exercises involving student participation, test or examination administrations, field trips, private conversations between students in the class or between a student and the faculty member is prohibited. Recordings may not be used as a substitute for class participation and class attendance and may not be published or shared without the

written consent of the faculty member. Failure to adhere to these requirements may constitute a violation of the USF Student Conduct Code – https://usf.app.box.com/v/usfregulation60021 .

XX. **Course Notes and Recording**

USF System Policy 10-048
http://regulationspolicies.usf.edu/policies-and-procedures/pdfs/policy-10-048.pdf

- B. Notes, recordings, handouts, and other material provided by the instructor **cannot** be exchanged or distributed for commercial purposes or for any purpose not related to a student's study or enrollment absent the express written authorization of the instructor.

- C. Selling or distributing notes, handouts, etc., without authorization or using them for any commercial purpose without the express written permission of USF and the instructor is a violation of the USF Student Code of Conduct - USF System Regulation 6.0021 (http://regulationspolicies.usf.edu/regulations/pdfs/regulation-usf6.0021.pdf).

XXI. **Course Policies: Grades (as applicable)**

Late Work Policy

Quizzes and assignments turned in late will be assessed with a 20% penalty of the earned grade each late day.

Extra Credit Policy

There is no extra credit. The instructor may consider giving extra credit problems only under very special conditions.

Grades of "Incomplete"

The current USF policy concerning incomplete grades will be followed in this course.

For 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.

Campus Free Expression

It is fundamental to the University of South Florida's mission to support an environment where divergent ideas, theories, and philosophies can be openly exchanged and critically

evaluated. Consistent with these principles, this course may involve discussion of ideas that you find uncomfortable, disagreeable, or even offensive.

In the instructional setting, ideas are intended to be presented in an objective manner and not as an endorsement of what you should personally believe. Objective means that the idea(s) presented can be tested by critical peer review and rigorous debate, and that the idea(s) is supported by credible research.

Not all ideas can be supported by objective methods or criteria. Regardless, you may decide that certain ideas are worthy of your personal belief. In this course, however, you may be asked to engage with complex ideas and to demonstrate an understanding of the ideas. Understanding an idea does not mean that you are required to believe it or agree with it.

Make-up Exams Policy
There is no makeup for all evaluative tasks: quizzes or assignments or exams.
<u>Documented</u> excused absences for due quizzes and assignments, **maybe** allowed by making arrangements ahead of time (when possible) by providing a reasonable amount of time to make up missed work.

Exam Retention Policy
 The student work will be digitally retained for one semester following the current one.

Group Work Policy
There is no group work in this course. We expect all work to be completed individually.

Final Examinations Policy
There are no exams in this course. There is continuous evaluation in the course.

XXII. **Course Policies: Technology and Media (as applicable)**
Canvas: This course will be offered via USF's learning management system (LMS), Canvas. If you need help learning how to perform various tasks related to this course or other courses offered in Canvas, please view the following videos or consult the Canvas help guides. Contact USF's IT department at (813) 974-1222 or help@usf.edu**.**

XXIII. **Course Policies: Student Expectations**
Title IX Policy
Title IX provides federal protections for discrimination based on sex, which includes discrimination based on pregnancy, sexual harassment, and interpersonal violence. In an effort to provide support and equal access, **USF has designated all faculty (TA, Adjunct, etc.) as Responsible Employees, who are required to report any disclosures of sexual harassment, sexual violence, relationship violence or stalking.** The Title IX Office makes every effort, when safe to do so, to reach out and provide resources and accommodations, and to discuss possible options for resolution. Anyone wishing to make a Title IX report or seeking accommodations may do so online, in person, via phone, or

email to the Title IX Office. For information about Title IX or for a full list of resources please visit: https://www.usf.edu/title-ix/gethelp/resources.aspx. *If you are unsure what to do, please contact Victim Advocacy – a confidential resource that can review all your options – at 813-974-5756 or va@admin.usf.edu.*

Course Hero / Chegg Policy

The USF Policy on Academic Integrity specifies that students may not use websites that enable cheating, such as by uploading or downloading material for this purpose. This does apply specifically to Chegg.com and CourseHero.com – any use of these websites (including uploading proprietary materials) constitutes a violation of the academic integrity policy.

ChatGPT, Generative AI, or other LLM: If you choose to use it, you shall disclose what was used and how. Lack of disclosure will be considered Academic Dishonesty. Be aware that the AI will receive a grade for what has done, and you get the rest of the grade for what you have done.

WhatsApp, GroupMe, and Student-to-Student Communication:

While students may use digital communication tools (WhatsApp, GroupMe, Discord, etc.) to communicate with fellow students, it is important to remember that academic integrity policies still apply in these environments. Informing others about the contents of tests is prohibited by the official regulation, as is receiving unauthorized information about an examination. Students are expected and required to immediately report instances of such violations to the instructor.

Automated Plagiarism Checkers:

In this course, automated plagiarism checkers such as turnitin.com and MOSS, will be utilized. Turnitin is an automated system which instructors may 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. Accordingly, you will be expected to submit all assignments report in electronic format. After the assignment is processed, as instructor I 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. Written reports are due at turnitin.com the same day as in class.

We may use the MOSS code checker https://theory.stanford.edu/~aiken/moss/ to check for code plagiarism. Moss (for a Measure Of Software Similarity) is an automatic system for determining the similarity of programs.

We may use automated AI checker on your submitted code and reports.

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.

Netiquette Guidelines
1. Act professionally in the way you communicate. Treat your instructors and peers with respect, the same way you would do in a face-to-face environment. Respect other people's ideas and be constructive when explaining your views about points you may not agree with.
2. Be sensitive. Be respectful and sensitive when sharing your ideas and opinions. There will be people in your class with different linguistic backgrounds, political and religious beliefs or other general differences.
3. Proofread and check spelling. Doing this before sending an email or posting a thread on a discussion board will allow you to make sure your message is clear and thoughtful. Avoid the use of all capital letters, it can be perceived as if you are shouting, and it is more difficult to read.
4. Keep your communications focused and stay on topic. Complete your ideas before changing the subject. By keeping the message on focus you allow the readers to easily get your idea or answers they are looking for.
5. Be clear with your message. Avoid using humor or sarcasm. Since people can't see your expressions or hear your tone of voice, meaning can be misinterpreted.

Email and Discussion Board Guidelines
1. Use the subject line effectively by using a meaningful line of what your email or discussion is about.
2. Keep your emails and postings related to the course content. You should not post anything personal on a discussion board, unless is requested by the instructor.
3. Any personal, course or confidential issues should be directly communicated to the instructor via email. The discussion boards are public spaces; therefore, any issues should not be posted there.

XXIV. Learning Support and Campus Offices

Academic Accommodations
Students with disabilities are responsible for registering with Student Accessibility Services (SAS) in order to receive academic accommodations. For additional information about academic accommodations and resources, you can visit the SAS website.
[SAS website for the Tampa and Sarasota-Manatee campuses.](#)
[SAS website for the St. Pete campus.](#)

Academic Support Services
The USF Office of Student Success coordinates and promotes university-wide efforts to enhance undergraduate and graduate student success. For a comprehensive list of

academic support services available to all USF students, please visit the [Office of Student Success website](#).

Canvas Technical Support

If you have technical difficulties in Canvas, you can find access to the Canvas guides and video resources in the "Canvas Help" page on the homepage of your Canvas course. You can also contact the help desk by calling 813-974-1222 in Tampa or emailing [help@usf.edu.](#)
[IT website for the Tampa campus.](#)

Center for Victim Advocacy

The [Center for Victim Advocacy](#) empowers survivors of crime, violence, or abuse by promoting the restoration of decision making, by advocating for their rights, and by offering support and resources. Contact information is available online.

Counseling Center

The Counseling Center promotes the wellbeing of the campus community by providing culturally sensitive counseling, consultation, prevention, and training that enhances student academic and personal success. Contact information is available online.
[Counseling Center website for the Tampa campus.](#)
[Counseling Center website for the St. Pete campus.](#)
[Counseling Center website for the Sarasota-Manatee campus.](#)

Tutoring

The Tutoring Hub offers free tutoring in several subjects to USF undergraduates. Appointments are recommended, but not required. For more information, email [asctampa@usf.edu.](#)
[Tutoring website for the Tampa campus.](#)

Writing Studio

The Writing Studio is a free resource for USF undergraduate and graduate students. At the Writing Studio, a trained writing consultant will work individually with you, 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, email [writingstudio@usf.edu](#).
[Writing studio website for the Tampa campus.](#)

XXV. **Important Dates to Remember**

Add a short statement that describes that all the dates and assignments are tentative and can be changed at the discretion of the professor. For important USF dates, see the [Academic Calendar](#) at http://www.usf.edu/registrar/calendars/