GEOG 3165: Geospatial Artificial Intelligence

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Course Description

Geospatial Artificial Intelligence (GeoAI) combines geospatial data with artificial intelligence (AI) techniques to analyze, interpret, and model spatial patterns and processes. This interdisciplinary field integrates machine learning and deep learning with geographic information systems (GIS) and remote sensing technologies to extract meaningful insights from geospatial data. GeoAI enables more accurate mapping, modeling and prediction of geographic phenomena to support decision-making, and has been widely adopted in various domains, including environmental monitoring, disaster response, agriculture, urban planning, energy, transportation, etc.

In this course, students will dive into the core principles and building blocks of GeoAI with a strong emphasis on real-world geographic applications. Key topics include machine learning, neural networks, and deep learning fundamentals, as well as the use of deep learning models to analyze geospatial data (e.g., satellite imagery, drone imagery and LiDAR point cloud data) for classifying, detecting, and extracting geographic features. Example applications include leveraging GeoAI models for land cover mapping, electric power lines identification, fire damage assessment, landslide susceptibility evaluation, etc. Students will also explore advanced GeoAI topics such as geo-foundation models and the most recent ChatGPT-like tools that are developed to automate spatial analysis and map-making workflows. Hands-on exercises, assignments and student projects in this class will involve using GIS tools (e.g., ArcGIS Pro), and AI frameworks to fine-tune existing, or develop and train new, GeoAI models and apply them for various case studies. Through this course, students gain experience using GeoAI methods to improve geospatial data analysis to support decision-making in application scenarios such as resource management and disaster response.

This upper level undergrade/graduate course is designed for students from diverse backgrounds in geography, computer science, or engineering, aiming to equip them with practical skills to apply GeoAI methods and techniques to tackle global environmental challenges.

Learning Outcomes

Upon completion of this course, students should be able to:

- Understand the concepts and terms in artificial intelligence, machine learning, deep learning and GeoAI.
- Know commonly used GeoAI models for remote sensing image classification,

object detection, and feature extraction.
- Be proficient in developing and training or fine-tuning GeoAI models and applying them for geospatial data processing and interpretation (e.g., land cover mapping).
- Comprehend the general steps of developing and/or applying GeoAI models.
- Apply the knowledge and skills of GeoAI to real-world applications.
- Work individually or in a small team to conceive, plan and implement a final project, and effectively communicate findings.

Prerequisites

Students are expected to have taken GEOG 2100 (Intro to GIS), and GEOG 3130 (GIS Programming with Python), or equivalent GIS and Python programming courses.

Special note: In addition to using classroom computers, each student needs to bring their personal laptop computer (Mac, Windows, or Linux) to use for this class.

Textbook

Required:

- Gao, S., Hu, Y., and Li, W. (Eds.). 2023. **Handbook of Geospatial Artificial Intelligence**. CRC Press. ISBN: 978-1-032-31166-1. https://doi.org/10.1201/9781003308423.
  [Electronic version of this book is freely accessible through DU library; search for the tittle at https://library.du.edu/ and sign into O'Reilly Learning Platform with your DU credential].

- Huang, X., Wang, S., Wilson, J., Kedron, P. **GeoAI and Human Geography: The Dawn of a New Spatial Intelligence Era**. Springer.
  [Electronic version of this book is freely accessible at https://link.springer.com/book/10.1007/978-3-031-87421-5 through DU library subscription]

- Zhang, A., Lipton, Z.C., Li, M. and Smola, A.J. 2023. **Dive into deep learning**. Cambridge University Press.
  [This book is freely available online at https://d2l.ai/. We will use the *PyTorch* version].

Additional readings (e.g., journal articles and/or book chapters) **will be posted on Canvas**.

Format

This course will be run as a combination of lecture discussion, and hands-on exercises. Each instructional period will take the following format:

- For each class period you are assigned a set of *readings* (to prepare for the new topic).
- At the beginning of each class, we can discuss any *questions* you may have in previous materials.
- Then we will discuss the new material for the day, led by the instructor or sometimes by students (i.e., students presenting assigned reading).
- After that you will work on in-class *exercises* to reinforce your learning.
- Time permitting, you may be given class time to work on the *assignments* or *projects*.

Course Requirements & Grading

Readings: Come prepared for each class period having completed the assigned *readings* for each module posted on Canvas. Readings are ungraded.

Exercises: For each instructional period, a set of exercises will be given. Exercises reinforce learning and understanding of conceptual ideas and technical skills. Exercises constitute **30%** of your overall grade for undergraduate students and **20%** for *graduate students*.

Assignments: There will be three assignments. The assignments constitute **30%** of your overall grade.

Quizzes: There will be two quizzes testing students' understanding of course materials. The quizzes constitute **20%** of your overall grade.

Paper presentation (*graduate students* only): Each graduate student is required to thoroughly read an assigned paper from the reading list and then summarize and present the paper to the class. The presentation constitutes **10%** of the overall grade for **graduate students**.

Term project: Students will apply the concepts and skills they learned in this course by completing a term project of their choosing. *Graduate students* are expected to work on the project individually. Undergraduate students can choose to team up (no more than two undergraduate students per team). The project constitutes **20%** of your overall grade. Instructions for the term project will be posted on Canvas.

	Undergraduate	Graduate
Exercises (weekly)	30%	20%
Assignments (3)	30%	30%
Quizzes (2)	20%	20%
Presentation	N/A	10%
Term project	20%	20%
Total	**100%**	**100%**

Grading criteria:

93-100%	A
90-92.99%	A-
87-89.99%	B+
83-86.99%	B
80-82.99%	B-
77-79.99%	C+
73-76.99%	C
70-72.99%	C-
67-69.99%	D+
63-66.99%	D
60-62.99%	D-
< 60%	F

Policies

[1] **Assignment submission**: You are encouraged to submit all work electronically through the Canvas course website. However, if you prefer to complete work on paper, you can also turn in handwritten work for grading.

[2] **Late submission of exercises and assignments will result in an automatic 10% reduction per day. Any submission more than a week late will receive 0 points.** You are expected to complete each exercise during the scheduled class session.

[3] **Academic Misconduct.** Most work submitted in this class is to be an individual effort (except for team project). Although working collaboratively on exercises/assignments in small groups (2-3 people) is allowed, **each student must complete and submit their own work**. Submitting the work of others, in total or in part, or providing work to others to be submitted as their own, **will result in a zero for the exercise/assignment.** For the consequences of violating the Academic Misconduct policy, refer to the University of Denver website on the Honor Code. See Student Rights & Responsibilities websites for information on the Student Conduct Policies and Procedures.

[4] **Special accommodation for students with disabilities.** Students who have disabilities or medical conditions and who want to request accommodations should contact the Student Disability Services (SDS) (https://studentaffairs.du.edu/disability-services-program or 303-871-3241).

[5] **Religious Accommodations**. University policy grants students excused absences from class or other organized activities or observance of religious holy days, unless the accommodation would create an undue hardship. You must notify me by the end of the first week of classes if you have any conflicts that may require an absence. It is your responsibility to make arrangements with me in advance to make up any missed work or in-class material.

[6] **Student Athletes**. If you are a student athlete, you should inform me of any class days to be missed due to DU sponsored varsity athletic events in which you are participating. Please provide me with an absence policy form by the end of the first week of class. You will need to make up any missed lectures, exercises, and/or assignments.

[7] **Inclusive Learning Environments**: In this class, we will work together to develop a learning community that is inclusive and respectful. Our diversity may be reflected by

differences in race, culture, age, religion, sexual orientation, socioeconomic background, and myriad other social identities and life experiences. The goal of inclusiveness, in a diverse community, encourages and appreciates expressions of different ideas, opinions, and beliefs, so that conversations and interactions that could potentially be divisive turn instead into opportunities for intellectual and personal enrichment.

A dedication to inclusiveness requires respecting what others say, their right to say it, and the thoughtful consideration of others' communication. Both speaking up and listening are valuable tools for furthering thoughtful, enlightening dialogue. Respecting one another's individual differences is critical in transforming a collection of diverse individuals into an inclusive, collaborative and excellent learning community. Our core commitment shapes our core expectation for behavior inside and outside of the classroom.

[8] **Title IX**: Gender violence can happen to anyone regardless of race, class, age, appearance, gender identity, or sexual orientation. The University of Denver is committed to providing an environment free of discrimination on the basis of sex (gender), including sexual misconduct, sexual assault, relationship violence, and stalking. The Center for Advocacy, Prevention and Empowerment (CAPE) provides programs and resources to help promote healthy relationships, teach non-violence and equality, and foster a respectful and safe environment for all members of the University of Denver community. All services are confidential and free of charge. For assistance during business hours, call 303-871-3853 and ask to speak to the Director of CAPE. After hours, please call the Emergency & Crisis Dispatch Line at 303-871-3000and ask to speak to the CAPE advocate on call.

[9] **Communication**: For any questions, please either come to my office hour, post on the Canvas course discussion forum, send Canvas messages emails to the instructor. The instructor will closely monitor these channels and usually will respond within 24 hours.

Course Calendar (**E**: Exercise; **A**: Assignment; **P**: Project; **Q**: Quiz)

The following class schedule is subject to change. You are responsible for keeping up with the readings, lectures, quizzes, and assignments. Any changes to this schedule will be announced in class and posted to the course Canvas page.

Week	Topics	Learning Activities
1	Introduction and overview	
Tue	Introduction and course overview	**E**: Google Colab.
Thu	Machine learning (ML)	**E**: Boston housing prices
2	Neural networks	
Tue	Neural network (NN) fundamentals	**E**: NN preliminaries
Thu	Linear neural networks	**E**: NNs for regression & classification
3	Convolutional neural networks	**A**: A1 posted
Tue	Convolutional neural network (CNN) fundamentals	**E**: CNN fundamentals
Thu	LeNet	**E**: LeNet
4	Deep neural networks	
Tue	Deep convolutional neural networks	**E**: Deep learning fundamentals
Thu	AlexNet	**E**: AlexNet

5	Pretrained DL models in ArcGIS	**Q**: Quiz 1; **A**: A2 posted
Tue Thu	Object detection using pretrained DL models Pixel classification using pretrained DL models	**E:** Wind turbines (RS imagery) **E**: High-resolution land cover (drone imagery)
6	DL model training in ArcGIS	
Tue Thu	Training DL models for image classification Training models using automated DL	**E:** Informal settlement (drone imagery) **E:** Land cover classification (SAR imagery)
7	DL model fine-tuning	**A**: A3 posted
Tue Thu	Tuning DL models using transfer learning in ArcGIS Fine-tuning YOLO for object detection	**E**: Building footprints (RS imagery) **E**: Homeless camps (Google Street View images)
8	Geo foundation models and GPTs	**Q**: Quiz 2
Tue Thu	Geo-foundation models LLMs, GeoGPTs, AutoGIS and MapGPT	**E:** NASA-IBM Prithvi & Google Earth AI **E:** Geo GPTs
9	Term project	
Tue	**P**: Proposal presentation	
Thu	P: Project implementation	
10	Term project	
Tue	P: Project implementation	
Thu	**P**: Project presentation	
11	**Project report due**	