CSCI-461: Artificial Intelligence for Sustainable Development

Units: 4

Fall 2023 – Mon/Wed 4:00pm-5:50pm

Location: KAP146

Instructor: Bistra Dilkina
Office: SAL 304
Office Hours: 1 fixed-time office hour plus by appointment.
Wed 11 am - 12 pm
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Teaching Assistant: TBD
Office: TBD
Office Hours: 2 fixed-time office hours with TA
Contact Info: TBD

Course Catalogue Description
Hands-on AI for Sustainable Development: learn about data mining, ML, optimization, and fairness in the context of applications with environmental and societal benefit; team projects with real-world relevance.

Course Description

The course will focus on understanding how AI can be leveraged for social good and for making progress towards sustainable development. It will introduce AI concepts spanning *data mining, machine learning (classification, regression, ensembles, deep learning, feature importance), decision making and optimization, and fairness in machine learning and algorithmic decision making* in the context of informing applications in *environmental sustainability (biodiversity, climate, water, forests), disasters and climate change, poverty, homelessness, and health*. It will expose students to both core AI knowledge as well as cutting edge research on the topic of using AI for social good applications. This course will introduce material through textbook reading, lectures and academic research papers reading. In-class Python tutorials and individual Python assignments using real datasets will give students hands-on practice of the concepts and algorithms covered. In teams, students you will experience *end-to-end the process of completing an applied AI project in the context of a societal or environmental domain*. The class will provide many opportunities for interactions with other students, the instructor and TA.

Learning Objectives
Students will be able to:

1. Describe and apply AI methods covered in the course, including the basic concepts and the key algorithms
2. Describe pressing societal and environmental challeges, where AI has been successfully deployed to tackle them
3. Model societal challenges as mathematical problems that AI techniques can be applied to and recognize which AI techniques fit the problems
4. Prototype ML applications in Jupyter Notebook, including the full pipeline of a data-driven project

Prerequisite(s):

1. CSCI-270
2. CSCI-360 or CSCI-467 or by instructor approval. D-clearance form: https://forms.gle/7Ra8CCTv2tBz3uqE6

Recommended Preparation: Python programming skills are strongly enrouraged (classes that use Python depending on instructor: CSCI 353, CSCI 360, CSCI 445, EE 250, EE 364, also ITP 115 as introduction to Python). All coding assignments will be based on Python so students should either already have Python skills or be prepared to learn on their own in

parallel with the course. Examples will be provided in the form of Python tutorials and scaffolding for assignments.

Course Notes
The class is letter grade. Readings and slides will be posted to Blackboard. We will use Slack for Q&A and open discussions among students as well as Instructor and TA.

The class will provide many opportunities for interactions with other students, the instructor and TA. Please stop by my office during posted office hours. It can be to discuss course content, brainstorm ideas, ask a question about USC or careers, or just to stop by and say hello. If you cannot attend my posted office hours, please email me to arrange another time that is convenient for both of us.

Required Readings and Supplementary Materials
At this time, the growing area of AI applications in sustainable development and social good has not yet been formalized in a textbook. Therefore, most of the readings will be based on research papers and articles that will be provided to the class as PDF based handouts via Blackboard.

The following books provide useful background information about the techniques studied in class. However, they do not discuss the application to specific social good settings.

(PRML) Pattern Recognition and Machine Learning, Christopher Bishop, Springer; 2006

(ISLR) An Introduction to Statistical Learning with Applications in R, Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani, Springer, 2013.
Available at http://faculty.marshall.usc.edu/gareth-james/ISL/ISLR%20Seventh%20Printing.pdf

(DL) Deep Learning, Goodfellow, I., Bengio, Y. and Courville A., 2016.

(MP) Applied Mathematical Programming. Bradley, Hax, and Magnanti (Addison-Wesley, 1977). Available at http://web.mit.edu/15.053/www/AMP.htm

Description and Assessment of Assignments
Paper reviews
The course will explore the course topics through a series of assigned readings in the form of research papers (and book chapters). Students will be assigned 1 research paper to read for a given week and submit a 1-2 page review for the assigned reading paper as homework. There will be 6 (+ 1 optional) such paper reviews assigned through the semester. Reviews will be assessed based on answering the following 5 questions (based on clarity and correctness):

1. What is the main problem/task addressed by the paper?
2. Why was AI needed and what AI approach was employed?
3. What does the paper's literature review suggest has been done previously, and how does the paper expand this previous work?
4. What data was used and were stakeholders / partner organizations engaged?
5. Discussion: what generalization to other settings/problems or what extension of the paper could be done?

Coding Assignments
Students will implement techniques studied in class by completing Python notebook assignments. The assignments will be graded based on completion and correctness.

Class Presentation
Students will present individually or in small groups (depending on class size) an AI for Social Good research paper to the class. The paper will be selected from a list of papers selected by the instructor, or outside of the selected list with instructor permission. The presentations will be graded on clarity, completeness, and presentation style.

Peer presentation learning
Peer learning during student presentations will be assessed with a short questionnaire on each student presentation in terms of relevance to technical and social good course themes.

Semester Project
Students will work in small groups to carry out a class project. The focus of the class project will be to develop an innovate application of AI to address a social good problem. Students will leverage tools, concepts, and techniques presented in the class. The project involves identifying a problem related to social good, data sources available to inform the problem, and AI-based approaches to it. The project will involve: data cleaning and fusion, data exploration/preporcessing/visualization, implementing at least 2 competing AI approaches, presenting results in terms of a table of multiple (at least 3) evaluation metrics and possible visualizations of outputs, and a discussion. Project topics will be suggested by the instructor, and also students will have the freedom to propose their own. The grade for the project will be based on the successful completion of the agreed upon project objectives. The deliverables include a project proposal (1-2 pages single space), premlinary paper draft (4-8 pages single space), final presentation (10-20 minutes) and a final report (10-15 pages single space). Examples of past projects (proposals, paper drafts, presentation and report) will be shared wit the class (with persmission from past students). They will be graded based on clarity, and completeness. The project is total 55% of final grade broken into deliverables throughout the semester as listed in Grading Breakdown.

Grading Breakdown

The grades for the students will be based on completion of the paper review assignments, presentation of a research paper, programming assignments, and a semester project. The breakdown for each of these categories is listed below. A more detailed explanation of the grading for each category is also provided.

Assessment Tool (assignments)	**% of Grade**
Class participation	2%
Paper Reviews	9%
Python assignment (4x4%)	16%
Class Presentation	15%
Peer Class Presentation Quizzes	3%
Project Proposal	5%
Project Preliminary Paper Draft	10%
Project Final Presentation	10%

Project Final Paper	30%
TOTAL	100%

Assignment Submission Policy
Assignments will be submitted via Blackboard.

Grading Timeline
Grades will be provided within 2 weeks of submission of the respective assignment.

Additional Policies
This is a discussion-based course, hence consistent attendance is expected. Missed classes with a valid excuse are allowed. Class participation will be scored based on engagements in course discussions. Class participation will be evaluated based on Q&A and engaging in discussions in class or on the class chat. At least 6 meaningful class interactions are needed to get full participation score. Meaningful interaction could be asking or answering questions during lecture, commenting on a paper being presented by the instructor or other students, or presenting updates on project progress, among others.

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Deliverables
Week 1	Introduction + Jupyter Notebooks Tutorial	
Week 2	Clustering + Clustering Tutorial / Clustering for Climate	Paper review 1
Week 3	Regression (Cross-Validation, Features Selection) / Applications	Python assignment 1: clustering
Week 4	Regression / Applications	Paper review 2 Python assignment 2: regression
Week 5	Classification (Trees, Ensembles, Feature Importance) / Applications	Project Proposal
Week 6	Deep Learning & Remote Sensing / Applications	Paper Review 3
Week 7	Student Paper Presentations	Paper Presentations + Reading (Quiz)
Week 8	Student Paper Presentations	Paper Presentations + Reading (Quiz) (Optional paper review)
Week 9	Student Presentations; Submodular Optimization / Applications	Paper Presentations + Reading (Quiz) Paper review 4
Week 10	Integer Programming Optimization / Applications	Python assignment 3: optimization
Week 11	Integer Programming Optimization / Applications	Project preliminary paper draft
Week 12	Multi-objective Optimization + Genetic Algorithms / Applications	Paper review 5
Week 13	AI & Fairness	Paper review 6
Week 14	AI & Fairness	Python assignment 4: fairness
Week 15	Project Presentations	Project Presentations
FINAL	Project Report	Due on University-scheduled date of the final exam

Papers covered in the class (subject to change):

Week 1: Introduction fo Sustainable Development + AI for Social Good Principles

- "Artificial intelligence for social good: A survey." Shi, Zheyuan Ryan, Claire Wang, and Fei Fang. arXiv preprint arXiv:2001.01818 (2020).
- "Computational sustainability: Computing for a better world and a sustainable future." Gomes et al. Communications of the ACM 62.9 (2019)

- The role of artificial intelligence in achieving the Sustainable Development Goals. Vinuesa, R., Azizpour, H., Leite, I. et al. Nature Communications **11,** 233 (2020). https://doi.org/10.1038/s41467-019-14108-y

Week 2: Data Mining / Environment

- Book: Introduction to Data Mining, by Tan, Steinbach, Kumar. Chapter 8. Cluster Analysis: Basic Concepts and Algorithms [can be downloaded at: http://www-users.cs.umn.edu/~kumar/dmbook/ch8.pdf], ISLR Ch. 10
- "Representativeness-based Sampling Network Design for the State of Alaska." Hoffman, Forrest M., Jitendra Kumar, Richard T. Mills, and William W. Hargrove. 2013. Landscape Ecology

Week 3+4: Regression / Energy + Climate Change

- PRML Chapter 3, ISLR Ch. 3, 5 & 6
- A Large-Scale Study on Predicting and Contextualizing Building Energy Usage . J. Zico Kolter, Joseph Ferreira. AAAI 2011
- A Machine Learning Approach to Modeling Human Migration. Caleb Robinson and Bistra Dilkina. ACM SIGCAS Conference on Computing and Sustainable Societies 2018

Week 5: Classification / Illegal Wildlife Poaching

- PRML Chapter 4 & 14, ISLR Ch. 4 & 8
- "Adversary models account for imperfect crime data: Forecasting and planning against real-world poachers." Gholami, Shahrzad, et al. AAMAS 2018.

Week 6: Deep Learning / Land Cover + Poverty

- PRML Chapter 5, DL Ch. 6 & 7
- "Combining satellite imagery and machine learning to predict poverty." Jean, Neal, et al. Science 2016.
- Large scale high-resolution land cover mapping with multi-resolution data. Robinson, C et al. In IEEE Conference on Computer Vision and Pattern Recognition 2019.

Week 9: Submodular Optimization / Environmental Sensing + Public Health

- Cost-effective outbreak detection in networks. Leskovec, J et al. In KDD 2007
- "Efficient sensor placement optimization for securing large water distribution networks." Krause, A. et al. Journal of Water Resources Planning and Management, 2008
- Using Social Networks to Aid Homeless Shelters: Dynamic Influence Maximization under Uncertainty. Amulya Yadav et al. AAMAS 2016

Week 10+11: Mathematical Programming / Biodiversity Conservation

- MP Chapters 1 & 9
- "Trade-offs and efficiencies in optimal budget-constrained multispecies corridor networks." Dilkina, Bistra, et al. Conservation Biology (2017)

Week 12: Multi-objective, Genetic Algorithms

- Deb, Kalyanmoy. "Multi-objective optimisation using evolutionary algorithms: an introduction." Multi-objective evolutionary optimisation for product design and manufacturing. Springer, London, 2011. Available at: https://link.springer.com/chapter/10.1007/978-0-85729-652-8_1

Week 13+14: AI and Fairness

- Tutorials: https://dssg.github.io/fairness_tutorial/, https://www.borealisai.com/en/blog/tutorial1-bias-and-fairness-ai/
- "Why Should I Trust You?": Explaining the Predictions of Any Classifier. Marco Tulio Ribeiro, Sameer Singh, Carlos Guestrin. In KDD, 2016
- A large-scale analysis of racial disparities in police stops across the United States. Pierson et al., https://arxiv.org/abs/1706.05678
- Julia Angwin, Jeff Larson, Surya Mattu, Lauren Kirchner, "Machine Bias". https://www.propublica.org/article/how-we-analyzed-the-compas-recidivism-algorithm

Statement on Academic Conduct and Support Systems

Academic Conduct:
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.
National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.
Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
ombuds.usc.edu
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.