UNIVERSITY OF MINNESOTA
Driven to Discover®

CSCI 5980/8980: Spatial Enabled Artificial Intelligence

Syllabus

Units: 3

Term — Day — Time: Spring 2022, MW – 4:00-5:15 pm

Location: Amundson Hall 120
Website: https://yaoyichi.github.io/spatial-ai.html

Instructor: Yao-Yi Chiang, PhD GISP
Office: Keller Hall 519
Regular Office Hours: Wednesdays after class
Contact Info: yaoyi@umn.edu

Teaching Assistant: Yijun Lin & Zekun Li
Office: TBD
Office Hours: TBD
Contact Info: lin00786@umn.edu; li002666@umn.edu

Course Description

The location of things in space and how they change over time is the key to understanding complex environmental phenomena and human-environmental interactions. A significant amount of data now contains location and time information, either explicitly, e.g., traffic sensors, air quality sensors, satellite imagery, or implicitly, e.g., images and text documents.

This course aims to explore the foundation and the state-of-the-art on 1) spatial data management and 2) machine learning & data mining technologies that can exploit the unique spatial data properties (e.g., autocorrelations) to solve real-world problems. This is a seminar course consisting of lectures and paper presentations. Specifically, this course has two main themes. The first theme explores current ways to store and manage spatial data, including topics in spatial databases, spatial Big Data platforms, and/or knowledge graphs & ontology. The second theme looks into how machine learning & data mining technologies solve real-world problems utilizing the unique spatial data properties, including topics in computer vision (e.g., object detection from overhead imagery), location time-series data mining (e.g., air quality prediction and trajectory mining), and optionally natural language processing (e.g., toponym detection from documents). The course will include several programming assignments and a final project.

Learning Outcome

Students will be able to identify the role of spatial data and challenges in using them to solve a real-world problem. They will define the problem scope by identifying appropriate machine learning and data mining technologies and then leveraging the unique spatial data properties to solve the problem. For example, students will learn how to find and integrate spatial data from heterogeneous sources in the assignments. Then they will learn how to build machine learning or data mining methods to handle these spatial data for descriptive and predictive analysis.

Recommended Preparation

The students should have excellent knowledge in applied machine learning (e.g., can select an appropriate machine learning model for solving a problem at hand) and databases (e.g., can write SQL queries with the help of the internet) and solid programming skills. Some background in handling spatial data is a plus but not required.

Course Notes

The course will be run as a lecture class with student participation strongly encouraged. There are weekly readings and students are encouraged to do the readings prior to the discussion in class. All of the course materials, including the readings, lecture slides, homework will be posted online.

Technological Proficiency and Hardware/Software Required

Students are expected to know how to program in a language such as Python. Students are also expected to have their own laptop or desktop computer where they can install and run software to do the weekly homework assignments.

Supplementary Readings

- [MMD] Jure Leskovec, Anand Rajaraman, Jeff Ullman, *Mining of Massive Datasets*
    - Cambridge University Press, 2012
    - Available free at: http://www.mmds.org/
- [SDB] Shashi Shekhar and Sanjay Chawla, *Spatial Databases: A Tour*
    - Prentice Hall, 2003 (ISBN 013-017480-7)
    - http://www.spatial.cs.umn.edu/Book/
- [DL] Ian Goodfellow and Yoshua Bengio and Aaron Courville, *Deep Learning*
    - MIT Press, 2016
    - Available free at: https://www.deeplearningbook.org/
- [Lin et al., 2017] Lin, Y., Chiang, Y.-Y., Pan F., Stripelis, D., Ambite, J. L., Eckel, S. P., and Habre, R. (November 2017). Mining Public Datasets for Modeling Intra-city PM2.5 Concentrations at a Fine Spatial Resolution. In *Proceedings of the 25th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*, Article No. 25, Redondo Beach, CA, USA
- [Li et al., 2020] Li, K., Wan, G., Cheng, G., Meng, L., & Han, J. (2020). Object detection in optical remote sensing images: A survey and a new benchmark. *ISPRS Journal of Photogrammetry and Remote Sensing*, *159*, 296-307.
- [Yue et al., 2019] Yue, M., Li, Y., Yang, H., Ahuja, R., Chiang, Y.-Y., and Shahabi, C. (December 2019). DETECT: Deep Trajectory Clustering for Mobility-Behavior Analysis. In *Proceedings of the 2019 IEEE International Conference on Big Data (Big Data)*, pp. 988–997, Los Angeles, CA, USA
- [Xingjian et al., 2015] Xingjian, S. H. I., Chen, Z., Wang, H., Yeung, D. Y., Wong, W. K., & Woo, W. C. (2015). Convolutional LSTM network: A machine learning approach for precipitation nowcasting. In *Advances in neural information processing systems* (pp. 802-810).
- [Qi et al., 2018] Qi, Z., Wang, T., Song, G., Hu, W., Li, X., & Zhang, Z. (2018). Deep air learning: Interpolation, prediction, and feature analysis of fine-grained air quality. *IEEE Transactions on Knowledge and Data Engineering*, *30*(12), 2285-2297.
- [Lin et al., 2020] Lin, Y., Chiang, Y.-Y., Franklin, M., Eckel, P. S., and Ambite, J. L. (November 2020). Building Autocorrelation-Aware Representations for Fine-Scale Spatiotemporal Prediction, In *Proceedings of IEEE International Conference on Data Mining (ICDM)*, pp. 352-361, Sorrento, Italy (9.8% acceptance rate)
- [Duan et al., 2021] Duan, W., Chiang, Y.-Y., Leyk, S., Uhl, J. H., and Knoblock, C. A. (December 2021). Guided Generative Models using Weak Supervision for Detecting Object Spatial Arrangement in Overhead Images. In *Proceedings of the 2021 IEEE International Conference on Big Data* (accepted), online
- [Vaswani et al., 2017] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. In *Advances in neural information processing systems* (pp. 5998-6008)

In addition to this list, students

may be given additional reading materials, such as research papers. Students are responsible for all assigned reading assignments.

Description and Assessment of Assignments

Homework Assignments: There will be 5 homework assignments and a final project. The assignments and final project must be done individually. Each assignment is graded on a scale of 0-100 and the specific rubric for each assignment is given in the assignment. Each submission will be checked for plagiarism.

Grading Breakdown

Quizzes: There will be weekly quizzes based on the material from the week before. There is no mid-term or final for this class.

Homework Assignments: There will be 5 homework assignments based on the topics of the class each week. The assignments must be done individually. Each assignment is graded on a scale of 0-100 and the specific rubric for each assignment is given in the assignment.

Final Project: There will be a final project based on the topics introduced in class. Suggested topics are:

MS/Senior Undergrad Students: A comparison of selected state-of-the-art methods for solving a spatial AI problem (e.g., object detection from satellite imagery).

MS/PhD Students: Develop a complete research work, which could be related to your research direction

Exams: There will be no midterm or final exams.

Grading Schema:

Quizzes	30%
Homework	50%
Final Project Proposal	5%
Final Project	15%
Total	100%

Grades will range from A through F. The following is the breakdown for grading:

94 – 100 = A	74 – 77 = C
90 – 94 = A-	70 –74 = C-
87 – 90 = B+	67 – 70 = D+
84 – 87 = B	64 – 67 = D
80 – 84 = B-	60 – 64 = D-
77 – 80 =C+	Below 60 is an F

Assignment Submission Policy

Homework assignments are due at 11:59 pm on the due date and should be submitted in Blackboard. You can submit homework up to one week late, but you will lose 20% of the possible points for the assignment. After one week, the assignment cannot be submitted. Every student has FIVE free late days for the homework assignments. You can use these five days for any reason separately or together to avoid the late penalty. There will be no other extensions for any reason. You cannot use the free late days after the last day of the class.

Schedule

	Topic	Application Theme and Readings	Deliverables/Due Dates
Week 1 1/17* Monday, 1/17 is a university holiday	**Introduction to Spatial AI** K-Nearest Neighbors Inverse Distance Weighting		
Week 2 1/24	**Spatial Data Management using Spatial Databases and Big Data Platforms** Spatial Databases MapReduce GeoMesa + Spark	SDB: Ch1 & 3 (free draft online) MMD: Ch2: Large-Scale File Systems and Map-Reduce	
Week 3 1/31			Homework 1 assigned
Week 4 2/7	**Spatial Data Analytics with Basic Data Mining and Machine Learning Algorithms** Air Quality Prediction Clustering Random Forest	MMD: Ch7: Clustering Lin et al., 2017	
Week 5 2/14			Homework 1 due, Homework 2 assigned
Week 6 2/21	**Capturing Spatial Dependencies with Deep Neural Networks** Object Detection and Semantic Segmentation for Overhead Imagery Understanding Deep Neural Networks Convolutional Neural Networks PyTorch	DL: Ch6&7 (optional) DL: Ch9 Li et al., 2020	
Week 7 2/28			Homework 2 due, Homework 3 assigned
Week 9 3/14	**Capturing Temporal Dependencies with Deep Neural Networks** Trajectory Mining AutoEncoder Recurrent neural networks, e.g., LSTM, GRU	Yue et al., 2019 DL: Ch10	Proposal presentation due
Week 10 3/21			Homework 3 due

	Sequence-to-sequence learning Proposal presentation		
Week 11 3/28	**Capturing Spatial and Temporal Dependencies with Deep Neural Networks** Air Quality Prediction ConvLSTM ConvLSTM + spatiotemporal heuristics	Xinjian et al., 2015 Qi et al., 2018	
Week 12 4/4	**Incorporating Spatial Statistics into DNN I** Air Quality Prediction Krigin ConvLSTM + representation learning	Lin et al., 2020	Homework 4 assigned
Week 13 4/11	**Incorporating Spatial Statistics into DNN II** Object Detection Variational AutoEncoder (VAE) VAE & Clustering Target-guided image classification	Duan et al., 2021	
Week 14 4/18			Homework 4 due, Homework 5 assigned
Week 15 4/25	**Latest Trends** Transformer Final Project Presentation	Vaswani et al., 2017	Project presentation due
Week 16 5/2* *Monday, 5/2 is the last day of class	Final Project Presentation		Homework 5 due

Statement on Academic Conduct and Support Systems

Academic Conduct[1]

You are expected to do your own academic work and cite sources as necessary. Failing to do so is scholastic dishonesty. Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using course materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, misrepresenting or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. (Student Conduct Code.) If it is determined that a student has cheated, the student may be given an "F" or an "N" for the course, and may face additional sanctions from the University.

The Office for Community Standards has compiled a useful list of Frequently Asked Questions pertaining to scholastic dishonesty.

Beware of websites that advertise themselves as being "tutoring websites." It is not permissible to upload any instructor materials to these sites without their permission or copy material for your own homework assignments from these various sites.

If you have additional questions, please clarify with your instructor for the course. Your instructor can respond to your specific questions regarding what would constitute scholastic dishonesty in the context of a particular class, e.g., whether collaboration on assignments is permitted, requirements and methods for citing sources, if electronic aids are permitted or prohibited during an exam.

Support Systems

A number of student services can be found on: https://onestop.umn.edu/ and https://disability.umn.edu/.

COVID-19

COVID-19, Face-Covering Requirement, Symptoms, Vaccination, and Boosters
The University requires all students and employees to be vaccinated or have a valid exemption; more information is at safe-campus website. On January 5, 2022 President Gabel announced an update on COVID-19 and campus operations which strongly encourages all community members to get a booster as soon as they are eligible. For information about getting a booster and how to schedule an appointment, please refer to **the University's Get the Vax 2.0 initiative.**

Stay at home if you experience any signs of illness or have a positive COVID-19 test result, and consult with your healthcare provider about an appropriate course of action. Absences related

[1] This is a direct copy from https://communitystandards.umn.edu/syllabus-insertion

to illness, including COVID-19 symptoms, for yourself or your dependents, are **excused absences** and I will work with you to find the best course of action for missed work and course content. I will follow these same protocols and will let you know if the delivery of this course has to be temporarily changed as the result of my own circumstances.

See below for additional details:

People who are not vaccinated are at high risk for getting and spreading SARS-CoV-2, the virus that causes COVID-19. New variants such as Omicron spread more easily and quickly which may lead to more cases of COVID-19 among college students this semester. Increases in the number of COVID-19 cases are straining healthcare resources.

The best defenses against contracting COVID-19 and spreading it to others are vaccination, masking, and taking measures to isolate when symptomatic or COVID-19 positive.

When indoors on campus, students, faculty, staff and guests are currently **required to wear a face covering (mask)**. You must wear your mask so that it covers both your nose and mouth. This will help protect all members of the community, and especially those who are immunocompromised and/or who are caretakers of others (e.g., young children) who are not yet vaccinated. Even though vaccinations are highly protective and required for all students and employees, breakthrough infections do occur; therefore, indoor masking continues to be one of our most important tools for ensuring sustained in-person learning. With the high transmissibility of the recent variants it is strongly recommended that you use an enhanced mask— a surgical mask either alone or in combination with a cloth mask, or an N95, KN95, AirPop or similar mask. Surgical masks are widely available throughout campus, and you can get free high-quality masks by following the instructions at https://www.uhs.umn.edu/university-health-and-safety-mask-support-program.

Both the Center for Disease Control (**CDC**) and Minnesota Department of Health (**MDH**) recommend that we stay home and get tested if we are experiencing **COVID-19 symptoms**, even if we're already fully vaccinated. I commit to doing my part to keep you and your peers safe by doing this, and I expect that you will too. If you experience **COVID-19 symptoms** or symptoms of any potentially infectious respiratory or other illness, you should stay home or in your residence hall room and not come to class or to campus. Consult your healthcare provider about an appropriate course of action, and refer to the **M-test program** for COVID-19 testing resources. If you test positive for COVID-19 here are the guidelines for **what to do**.

The above policies and guidelines are subject to change because the University regularly updates **pandemic guidelines** in response to guidance from health professionals and in relation to the prevalence of the virus and its variants in our community. Any changes in COVID-19 policy will be indicated in email messages from the Administration and these syllabus details will be modified as needed.