*Syllabus*

**Geographic Data Science: *Geospatial Big Data Analytics and Applications***

**Course Objective:**

This course empowers students with Data Science approaches, leveraging Geographic Big Data and data analytics to address urban environmental and societal challenges. Through hands-on experience with diverse real-world datasets, students will develop computational skills in harnessing the power of geographic Big Data, including but not limited to, geographic data management, geospatial analysis, text analytics, and spatial data mining and machine learning techniques.

**Datasets Used in This Course:**

Geo-located Social Media Data (Geo-located tweets)

* A collection of geo-located Twitter data with worldwide coverage (2014–2022).
* 2014 data will be used for course demonstrations. Students have access to all datasets for project work and for exploring topics of interest.

Mobile Device Location Data (SafeGraph)

* Public POIs (Points-of-Interest) covering the United States (2018-2021)
* Mobile device location data showing mobile device users’ visitation patterns to the POIs and their place of origins

Geo-tagged Photographs

* Geo-tagged photographs from GeoGraph with user-rated scenic scores (scenic perception and environmental aesthetics)

Spatial Networks

* OpenStreetMap (street networks)
* Social networks tied to geographic locations
* Spatial networks of interactions (e.g., human mobility/activity, movement/information/interaction flows, and physical/virtual connectivity)

**Course Schedule**

**Week 1: Introduction to Geographic Data Science (GDS)**

* The new paradigm of geographic Big Data and Geographic Data Science.
* Overview of GDS and its applications.
* Various types of geographic Big Data sources.
* Understand urban and population dynamics through the lens of Big Data.
* The potentials of GDS for addressing social and environmental challenges.

**Week 2: Computing Environment and Resources**

* Introduction to the state-of-art computational platforms/frameworks, such as high-performance computing (HPC) and distributed computing environments for GDS (introduction to cyberGIS).
* Remote access to computing resources (e.g., supercomputing resources provided by the ACCESS (<https://access-ci.org>) or GW-offered computing clusters).
* Cloud computing basics

**Lab 1:** Remote access to HPC/cloud, be familiar with the computational environment, perform data transfer, write and submit job scripts.

**Week 3: Geographic Data Management**

* Geographic datasets
  + location, location, location
  + tabular data, Shapefile, (geo)JSON, geo-tagged data (text and photo/image).
  + raster vs. vector
* Spatial databases and NoSQL (MongoDB)
  + spatial indexing
* Introduction to Apache Hadoop and Spark for Big Data query and processing

**Lab 2:** MongoDB data storage, queries, and indexing

**Week 4**: **Geospatial Operations and Geographic Big Data Analytics**

* Common/basic geospatial operations (nearest neighbor search, point-in-polygon, spatial join)
* Software (ArcGIS and QGIS), computing tools/frameworks (Python and related packages), and visualization tools/frameworks (web-based map interfaces)
* Case studies:
  + Geo-tagged tweets data pre-processing, e.g., extracting geo-locations of each tweet and other useful fields of information
  + Using geographical boundaries/units to extract data records fall in (e.g., SafeGraph data and geo-tagged tweets)
  + Illustrate the processes with Python scripts (available in Jupiter notebook)

**Lab 3 (Homework assignment 1)**: Python scripting with geo-located tweets, creating visualizations in QGIS/ArcGIS, and as overlays on OpenStreetMap)

**Week 5**: Text Analytics in Geographical Contexts

* Overview (scenarios and applications)
* Topic modeling (word cloud, TF/IDF, BERTopic)
* Topic classification (machine learning approaches: Scikit-learn based)
* Sentiment analysis (methods and applications)

**Lab 4:** Sentiment analysis with social media data and map visualizations

**Week 6**: Spatial Network Modeling and Analysis

Network Modeling:

* Spatial networks
* Real-world physical networks (constructing street networks as graphs)
* Real-world virtual networks (constructing a network of flows as graphs, e.g., movements captured by geo-located tweets and SafeGraph)

Network Analysis:

* Network centrality measures and applications
* Community detection concepts and methods

**Lab 5 (Homework assignment 2):** constructing spatial networks from OSM street networks, measure network parameters, and visualize the outputs

**Week 7:** Mid-term Project Proposal

* Submit an initial proposal for a final project of interest, outlining the research questions and methodology
* In-class presentation and peer feedback

**Week 8:** Exploratory Spatial Data Analysis (ESDA)

* Spatial Autocorrelation:
  + Moran’s I and Local Indicators of Spatial Association (LISA).
* Geospatial queries, spatial joins, buffering, overlay, and proximity analysis

**Lab 6:** ESDA applications with PySAL and GeoPandas

**Week 9**: Data-driven Approaches and Regression Models

* Estimate urban and population dynamics with geographic big data
* Socio-economic and demographic characteristics of regions from official statistics
* Implement regression models to capture significant impacting drivers/factors

**Lab 7:** Running regression models to identify significant socio-economic and demographic factors in affecting people’s visitations to the Smithsonian's National Zoo (Washington DC Zoo), a case study of regression analysis with SafeGraph data and American Community Survey data.

**Week 10**: Spatial Data Mining and Machine Learning - Part 1

* Spatial Machine Learning Fundamentals:
  + Traditional vs. spatial machine learning methods.
  + Supervised and unsupervised learning using spatial predictors.
* Spatial clustering methods (e.g., DBSCAN and HDBSCAN)

**Lab 8**: Spatial clustering and visualization

**Week 11**: Spatial Data Mining and Machine Learning - Part 2

* Introduction to spatially explicit neural networks and deep learning.
* Deep learning applications for geo-tagged text and images
* Predictive modeling using spatial predictors

**Lab 9 (Homework assignment 3):** Building spatial predictive models

**Week 12**: Geographic Data Science for Social Good – Part 1

Understanding Human Interactions with Urban Space:

* Understand urban dynamics through the lens of human mobility.
* Generate spatiotemporal insights of foot traffic/visitation to public points-of-interest with mobile location data (SafeGraph)
* Understand movement flows among different geographic units (counties, cities, and states) with dynamic temporal ranges

Geospatial Data Processing:

* Pinpointing social media text records (geotagged tweets) to spatial units (e.g., buildings, addresses, census tracts, counties, states).
* Using Python and GeoPandas for geospatial operations on large-scale datasets.

**Lab 10**: Geographic Data Fusion for Integrative Data Analysis:

* Combining social media data, mobile location data, and infrastructure datasets (e.g., subway access, EV charging stations, points of interest).

**Week 13**: Geographic Data Science for Social Good – Part 2

Exploring Social and Environmental Challenges:

* Evaluating environmental equity and exposure
* Case studies on environmental justice and public health (pollution exposure with SafeGraph data, environmental perception using GeoGraph data.)

Student-Led Discussions:

* Encouraging students to propose and discuss their own research topics related to social and environmental challenges.

**Lab 11 (Homework assignment 4)**:

* Mining social media data to evaluate public perception (sentiment/emotion) of metro transportation in Washington, D.C., using techniques covered in previous weeks.

**Week 14**: Final Project Presentations

* Students will work on a data-driven research project applying computational social science methods to analyze a social or environmental issue of their choice.
* The project will involve data acquisition, processing, analysis, and visualization, culminating in a final presentation.
* Students present their comprehensive geographic data science research projects.
* Written reports submission

**Grading:**

* Labs/Homework Assignments (weekly labs): 40%
* Mid-term Project Proposal: 15%
* Final Project and Presentation: 35%
* Participation/attendance and Student-led Discussions: 10%

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| **Score** | **Grade** |
| >= 90 | A (Excellent) |
| 85 − 89 | A- (Intermediate grade) |
| 80 − 84 | B (Good) |
| 75 − 79 | B- (Intermediate grade) |
| 70 − 74 | C (Fair) |
| 60 − 69 | D (Poor) |
| < 60 | F (Fail) |

**Homework Assignments:**

Weekly homework/labs designed to reinforce practical skills in geographic data science techniques, requiring submission through the course management system. Timely submission and correctness are essential for successful course completion.

**Course Materials:**

All lecture slides, lab instructions, code, and sample datasets are available in the GitHub repository (<https://github.com/yinjunjun/datascience>).

***Recommended reading materials:***

Yin, Junjun, Guangqing Chi, and Bin Jiang. "Unlocking the Secrets of Scenic Beauty: A Quantitative Analysis of Object Variety and Connections in Scenic Images." Journal of the Royal Society Interface (2025)

Yin, Junjun, Matthew Brooks, Donghui Wang, and Guangqing Chi. "Characterizing climate change sentiments in Alaska on social media." Digital Geography and Society 8 (2025): 100110.

Yin, Junjun, and Guangqing Chi. "A tale of three cities: uncovering human-urban interactions with geographic-context aware social media data." Urban Informatics 1, no. 1 (2022): 20.

Yin, Junjun, Yizhao Gao, and Guangqing Chi. "An evaluation of geo-located Twitter data for measuring human migration." International Journal of Geographical Information Science 36, no. 9 (2022): 1830-1852.

Alba, Charles, Bing Pan, Junjun Yin, William L. Rice, Prasenjit Mitra, Michael S. Lin, and Yun Liang. "COVID-19’s impact on visitation behavior to US national parks from communities of color: Evidence from mobile phone data." Scientific reports 12, no. 1 (2022): 13398.

Yin, Junjun, and Guangqing Chi. "Characterizing people’s daily activity patterns in the urban environment: A mobility network approach with geographic context-aware twitter data." Annals of the American Association of Geographers 111, no. 7 (2021): 1967-1987.

Yin, Junjun, Aiman Soliman, Dandong Yin, and Shaowen Wang. "Depicting urban boundaries from a mobility network of spatial interactions: A case study of Great Britain with geo-located Twitter data." International Journal of Geographical Information Science 31, no. 7 (2017): 1293-1313.

Jiang, Bin, Junjun Yin, and Sijian Zhao. "Characterizing the human mobility pattern in a large street network." Physical Review E—Statistical, Nonlinear, and Soft Matter Physics 80, no. 2 (2009): 021136.