CS225: Spatial Computing

Course Outline

Instructor: Amr Magdy

Computer Science and Engineering

www.cs.ucr.edu/~amr/

Welcome to CS 225

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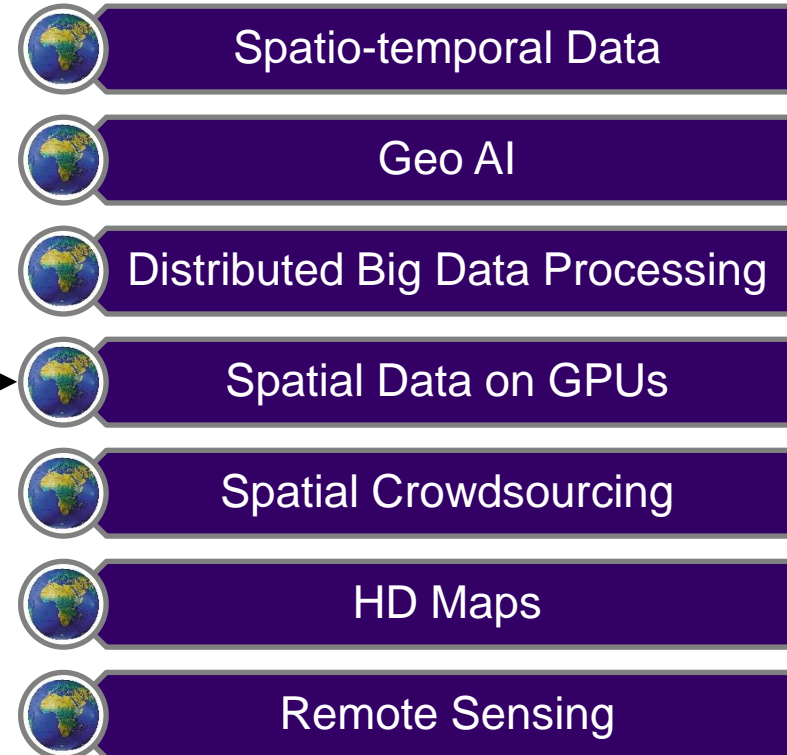> Course Website: https://www.cs.ucr.edu/~amr/#teaching

> Slack: https://join.slack.com/t/cs225-f23/shared_invite/zt-242fjnvjr-krHMNuwTfE6d3BedgHtBCQ

Course Content

› Introduction to Spatial Computing

› Spatial Relationships and
   Data Models

› Spatial Data Storage
   and Indexing

› Spatial Query Processing

› Spatial Networks

› Geo-visualization

› Spatial Data Mining

› Trends and Innovations in Spatial Applications

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- › Introduction to Spatial Computing

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- › Trends and Innovations in Spatial Applications

- Spatio-temporal Data
- Geo AI
- Distributed Big Data Processing
- Spatial Data on GPUs
- Spatial Crowdsourcing
- HD Maps
- Remote Sensing

Course Content

> Course Research Elements:

>> "Introduction to Research" lecture

>> Surveying the literature methodology

>> Paper reviews practice

>> Presenting research papers

>> Writing technical papers (survey and/or final report)

>> Project stages
(identifying idea, literature survey, tackling the problem, and documenting the results)

>> Lecture contents on new trends on spatial-related research

Grading and Policies

> Course work
>> Project + (Popup) Quizzes + Final Exam (70%)
>> Hands-on on spatial technologies (7.5%)
>> Class participation (Evaluating others) (5%)
>> Paper reviews (7.5%)
>> Presentations (10%)

> Delivery policies:
>> Groups of 5 students required for the project.
>> Delivery instructions and policies announced per assignment.

> Cheating is not allowed and will be reported
>> If you are using any external source, you must cite it and clarify what exactly got out of it.
>> You are expected to understand any source you use.

Project: Categories

› Novel Research

  › Preliminary investigation for a novel research idea

› Literature Survey Paper

  › Surveying the literature of a certain spatial topic

› Literature Experimental Evaluation

  › Experimentally compare major techniques of a certain spatial topic

› Vision Analysis

  › Track the advances in topics of a vision report (e.g., CCC Spatial Computing 2020 Workshop)

› Interdisciplinary project

  › Apply spatial computing technologies to a non-CS field

› Spatial Application

  › Apply spatial technologies to a real use case.

Project: Deliverables and Assessment

> Novel Research
>> Clearly identifying and presenting the research elements
>> Preliminary solution idea
>> Preliminary evaluation results

> Literature Survey Paper
>> Comprehensive list of papers
>> Literature classification/taxonomy
>> Manuscript quality (writing, figures, organization,...etc)

> Literature Experimental Evaluation
>> Long and short lists of papers
>> Evaluation outline and corresponding implementations from the short list (or a subset)
>> Evaluation results

Project: Deliverables and Assessment

> Vision Analysis
>> Itemized analysis of the vision report
>> Quality of surveying work on each topic

> Interdisciplinary Project
>> Clear problem definition and importance
>> Survey of related work
>> Quality of the main deliverable, e.g., script, program, etc

> Spatial application
>> Quality of the delivered software modules

Project: Joint CS225 & CS226 projects

> You can share project groups between CS 225 (Spatial Computing) and CS 226 (Big Data Management), given:

> > You work on one project with double in size, this gives opportunity to focus on one big project for the two courses.

> > At least four group members must be taking the two courses.

> > The project proposal must explicitly emphasize the spatial component and the big data component.

> > The project proposal must explicitly emphasize how the project size would be different if it belongs to only one course.

> > The project report will have a specific structure showing the contributions to each course.

Suggested Projects (Open MSc Projects for students admitted this quarter)

› Project 1: Spatial Clustering (Regionalization) on Euclidean vs. Spherical Spaces

This project evaluates the performance of Spatial Regionalization algorithms when the Earth is modeled as a projected Euclidean space versus a spherical space (specifically using Google S2 geometry). The project should identify performance bottlenecks that exist in spherical spaces. The outcomes will help the industry to optimize spatial clustering on their systems. The evaluation will span multiple clustering algorithms, and the project size could be adjusted based on the time budget available.

› Project 2: Implement a prototype of a Spatial Regionalization system

This project enables users to use spatial clustering algorithms through SQL-like interface. This project could be divided into multiple groups. For example, a team for the RQL query language parser and another team for the query executor. This paper gives details:

Hussah Alrashid, Amr Magdy: A Scalable Unified System for Seeding Regionalization Queries. SSTD 2023: 96-105

Suggested Projects (Open MSc Projects for students admitted this quarter)

› Project 3: Web-based application for Spatial Grouping and Counting Queries

This project will develop a web interface for users to easily use backend algorithms that use Apache Spark for big spatial data. The Spark algorithms perform grouping queries of spatial points, lines, and polygons. The project will be a front-end interface for a distributed Spark-based backend. The project could span one or two groups, depending on the type of selected queries.

› Project 4: Augmented GWR:
Implement the following paper with production-level quality for a release in an open-source library and develop a web-based demonstration for it.

Mohammad Reza Shahneh, Samet Oymak, Amr Magdy: A-GWR: Fast and Accurate Geospatial Inference via Augmented Geographically Weighted Regression. SIGSPATIAL/GIS 2021: 564-575

Suggested Projects

> **Literature Surveys**

1. Spatial Join Query Processing in Distributed Environments

2. Multi-language Spatial Keyword Search

3. Spatial Data Science Tools

Suggested Projects

› ESRI GeoAI tools

  › **ArcGIS and Microsoft AI: Scalable GeoAI in the Cloud**

    › https://www.youtube.com/watch?v=m7GqaC5_fFU

  › **Geo Artificial Intelligence**

    › GeoAI medium blogs

    › GeoAI Demonstration Gallery

  › **Geospatial Data Science**

    › Spatial Analysis and Data Science

    › R-ArcGIS Bridge

    › Bridging Into New Realms: R-ArcGIS Bridge and Microsoft R

    › R Notebooks in ArcGIS Pro for Spatial Data Science

    › ArcGIS API for Python – A powerful python library for spatial analysis, mapping and GIS

Suggested Projects

› ESRI GeoAI tools
  › Online Lessons:
    › [Use Deep Learning to Assess Palm Tree Health](#)
    › [Extracting Information using Image classification](#)
    › [Downscale Climate Data with Machine Learning](#)
    › [Predict Seagrass Habitats with Machine Learning](#)
    › [Identify and Ecological Niche for African Buffalo (with R-ArcGIS Bridge)](#)
    › [Analyze Crime using Statistics and R-ArcGIS Bridge](#)
    › [Analyzing violet crime using hot spot analysis and space time cube](#)

Project Bonus

› **Considerable bonus** will be given for using AI-based and LLM-based software development, such as using LangChain or similar frameworks

  › https://www.langchain.com/

› Seek instructor approval for frameworks other than LangChain

› **Considerable bonus** will be given for teaching colleagues about AI-based and LLM-based software development as a course activity

Paper Reviews and Presentations

> Two review assignment (7.5%)
>> Summarization of paper research elements
>> Paper critique

> Presentations (10%)
>> Papers are presented in groups, different from project groups.
>> Each group member must present.
>> Involve presenting research papers as well as relevant articles.
>> Open for new title suggestions.

Hands-on on Spatial Technologies

- › Any spatial technology is fine, check instructor approval
- › Any reasonable-sized hands-on is fine as well
- › Candidate technologies
  - › Spatial Databases
    - › PostGIS, Oracle Spatial, SpatiaLite, MonetDB/GIS, etc
  - › GIS Software
    - › ArcGIS, QGIS, etc
  - › Maps
    - › Google Maps, Bing Maps, ESRI Maps, etc
  - › ESRI Story Maps
  - › Big Spatial Data Systems
    - › Simba, SpatialHadoop, GeoSpark, SpatialSpark, etc
  - › GeoSpatial Analysis Tools
    - › PySAL, GeoPandas, Fiona, Shapely, GeoDa, SSN & STARS, SP and SF R packages, OGR GDAL

Final Exam and Quizzes

> Lectures content & presentations content

Sample Survey Papers

› In-Memory Big Data Management and Processing: A Survey. Hao Zhang, Gang Chen, Beng Chin Ooi, Kian-Lee Tan, and Meihui Zhang. TKDE, vol. 27, no. 7.

› A survey of top-k query processing techniques in relational database systems. Ihab F. Ilyas, George Beskales, Mohamed A. Soliman. ACM Computing Surveys (CSUR), Vol. 40, Issue 4, No. 11, Oc. 2008.

› Crowdsourced Data Management: A Survey. Guoliang Li, Jiannan Wang, Yudian Zheng, Michael J. Franklin. TKDE, vol. 28, issue 9.

R'GeoSpatial Student Club

WHAT'S GIS?

GIS stands for Geographic Information system. The software is used for both gathering and visualizing data. The most common example that is applicable to our lives is Google maps. Whenever you look up directions or try to figure out where you are, that's the byproduct of GIS.

GOAL OF THE CLUB:

R'geospatial is a relatively new club on campus that aims to show the utility and transferability of GIS skills to students' careers. The club will cover how to use the software and also how it applies to your major and future professional endeavors.

If interested, please add us on Highlanderlink and feel free to reach out to us if you have any questions!

Credits

- Prof. Shashi Shekhar course
  - http://www.spatial.cs.umn.edu/Courses/Spring18/8715/index.php
  - http://www.spatial.cs.umn.edu/Courses/Fall21/5715/index.php