GES 671: Launching Spatial Databases

Course Information

Course Title: GES 671: Launching Spatial Databases

Semester: Spring 2025

Instructor: Michael Haxel

Contact Information: Mhaxel1@umbc.edu

Office Hours: By appointment

Class Meeting Day/Time: Wednesday 6:00 - 8:30 pm

Location: Sondheim Hall, 007 – GIS Lab, University of Maryland, Baltimore County, 1099 Hilltop Rd, Baltimore, MD 21250

Course Description

This course provides a comprehensive, hands-on introduction to spatial databases, focusing on PostgreSQL and PostGIS for managing and analyzing geospatial data. Students will learn how to design, implement, and maintain relational databases while integrating geospatial data for analysis and visualization. The course begins with fundamental SQL concepts, including data definition, manipulation, and transaction control, before transitioning into database normalization, indexing, and optimization techniques. Students will also explore metadata documentation, entity-relationship modeling (ERD), and database security to ensure effective data governance and integrity.

A key component of this course is its applied learning approach, where students will complete structured lab assignments involving SQL scripting, spatial queries, and data visualization using ArcGIS Pro. Through progressively complex database tasks, students will gain the ability to work with spatial indexes, advanced spatial functions, user access control, and differing database environments data. The course culminates in a final project where students will design and implement a fully functional spatial database to solve a real-world problem, applying the full range of skills acquired throughout the semester.

By the end of the course, students will have a solid foundation in spatial database development, positioning them for careers in GIS database administration, geospatial analytics, and spatial data science.

Course Objective

Upon successful completion of this course, students will be able to:

- Design, develop, and manage relational spatial databases.
- Write and optimize SQL queries for data retrieval and analysis.
- Apply normalization principles to improve database efficiency.
- Utilize PostGIS for spatial data storage, indexing, and querying.
- Document metadata and business processes to support data integrity.

Course Google Drive

The following link is an alternative way to accessing course materials as opposed to using Blackboard.

Assignments & Evaluations

Exams & Assessments

There are no exams in this course. As an applied course, the emphasis is placed on hands-on assignments completed throughout the semester. Students will also engage in assessments related to assigned readings and instructional materials to reinforce their understanding of key concepts.

Assignments

Throughout this course, students will engage with real-world geospatial datasets and apply concepts introduced in lectures. Assignments will center around SQL query execution, database architecture, spatial analysis, and proper documentation practices. While students will follow demonstrated workflows from class, they will also be encouraged to develop independent approaches for tackling spatial database challenges. These assignments will emphasize:

- Understanding **SQL queries** and their role in spatial databases.
- Implementing **database normalization** and schema design.
- Applying spatial queries and functions using PostGIS.
- Documenting metadata and business workflows.
- Developing real-world GIS solutions based on best practices in data management.

Assignments must be completed using a combination of class materials, assigned readings, and independent research. Students are expected to clearly document their methodology and results.

Assignment Expectations

Per university guidelines, students should expect to spend **2+ hours per credit hour** outside of class. Given that this is a graduate-level course, students taking a full-time load should

anticipate dedicating **3+ hours per credit hour** to coursework. This means that outside of class, students are expected to:

- Conduct their own research into database and spatial analysis techniques.
- Explore PostgreSQL and PostGIS documentation to deepen their understanding.
- Troubleshoot SQL queries and optimize workflows independently.

The instructor is always available to provide guidance, but part of **graduate-level coursework** is learning to problem-solve independently using available documentation, online resources, and professional best practices.

Student Evaluation

Grading Criteria

To earn an **A**, students must demonstrate a strong grasp of both technical and conceptual aspects of spatial databases. This includes the ability to write optimized SQL queries, design efficient database schemas, implement spatial indexing, and document workflows effectively. A **B** will be awarded to students who show proficiency in one area but exhibit gaps in the other. A **C** or lower will be given if a student does not demonstrate sufficient knowledge or application of the course material.

All assignments will be weighted equally unless specified otherwise. The overall grade will be determined by the cumulative performance across all coursework, calculated as a percentage of total assignments completed.

For **Graduate Students**, grades will follow a plus/minus system:

- **90-100%** = A to A-
- **80-89%** = B+ to B-
- **70-79%** = C+ to C-
- Below 70% = F

For **Undergraduate Students**, grades will follow a whole-letter grading system:

- 90-100% = A
- 80-89% = B
- 70-79% = C
- 60-69% = D
- Below 60% = F

Assignment Evaluation

Evaluating database assignments requires both objective and subjective assessments. While SQL syntax and query results can be graded for accuracy, aspects such as database design,

workflow documentation, and spatial analysis methodology require qualitative evaluation. Students will be graded based on adherence to best practices taught in class, rather than external sources that may offer alternative database design philosophies.

Late Submission Policy

If a student cannot submit an assignment by the due date, they **must** do the following:

1. Notify the instructor **before** the deadline with a clear explanation.
2. Provide a revised due date that is no later than the start of the next class session.

If the revised due date is missed, a **full letter grade deduction** will be applied. Assignments not submitted within **two weeks of the due date** will receive a **zero**.

Grading & Evaluation

Assignment	Weight
Lab Assignments	40%
At-Home Assignments	25%
Final Project	25%
Participation & Engagement	10%

Late Submission Policy: Assignments submitted past the deadline will incur a **10% deduction per day** up to a maximum of 5 days, after which they will not be accepted unless prior arrangements have been made.

Writing Quality Expectations for Assignments and Exams

This course is part of a curriculum that awards a Masters in Professional Studies (M.P.S.) degree. Because the course requires students to describe –in writing– their interpretations of statistical results it is expected that students will generate products that meet the professional standards of such a program. One of the main facets of an M.P.S. is to gain an ability to clearly communicate analytical results to audiences of all types. All assignment and project products for this course will be evaluated on the student's ability to write a high-quality report of findings. Exercises and projects are designed to train students on how to professionally report analytical results in documents or write software code that others will read or use. This is an important facet in demonstrating the value of geography and spatial analysis over other forms of analysis. All products, written or coded, must be thoroughly

defined and polished. Poorly written assignments may be downgraded one letter from achieved grade.

UMBC offers two options for helping students improve their writing. The first is through the USG Center for Academic Success, who directly help students improve their writing. The second option is through the UMBC Writing Center, which offers online tutoring for ANY written assignment in ANY course during both summer sessions. Students may choose to chat synchronously online with a tutor, or submit a paper and receive asynchronous feedback. All appointments must be made at least one day in advance of meeting for a session. The following is a rubric for writing expectations:

Grade	*Style*	*Substance*
A	Clear and novel organization Accessible and concrete language Few mechanical errors Noteworthy graphics	Well-supported arguments Use of pertinent examples and facts Awareness of complexities Appropriate use of sources
B	Clear and competent organization Few sentence errors Well-prepared graphics	A few incorrect statements Adequately supported statements Appropriate secondary sources
C	Clear organization Adequate content Adequate graphics	Several incorrect statements Major arguments supported Inconsistent use of sources
D	Unclear organization Many mechanical errors Incomplete visual graphics	Many incorrect or unclear statements Unsupported arguments Irrelevant or misapplied examples

Plagiarism

Presenting someone else's work, whether written or verbal, as your own—whether in part or in full—without appropriate credit is a serious academic violation. This course, along with the Department and the University of Maryland, Baltimore County, maintains a **zero-tolerance policy** for plagiarism. UMBC defines plagiarism as:

"knowingly, or by carelessness or negligence, representing as one's own in any academic exercise the words, ideas, works of art or computer-generated information and images of someone else"

Students found guilty of plagiarism will be referred to the **Program Directors** and will be held accountable under university policies. Consequences of plagiarism can include failing an assignment, a reduction in the final course grade, or failing the course entirely. To avoid

plagiarism, students must properly cite all sources and ensure their work reflects their own understanding and effort.

Examples of plagiarism are:

- Submit someone else's work as your own.
- Buy a paper from a paper-mill, website or other source.
- Copy sentences, phrases, paragraphs, or ideas from someone else's work, published or unpublished, without giving the original author credit.
- Replace select words from a passage without giving the original author credit. ·
- Copy any type of graphics, tables, graphs, maps, or charts from someone else's work without giving the original author credit.
- Piece together phrases, ideas, and sentences from a variety of sources to write an essay.
- Build on someone else's idea or phrase without giving the original author credit.
- Using another person’s maps as your own or using another’s map as a foundation for making your own.
- Use Artificial Intelligence (AI) without reviewing and refining the output as is it output and does not use another author’s work that you are claiming to have produced.

Details about avoiding plagiarism, examples, and disciplinary policies should be reviewed to gain a clear understand prior to working on an assignment or exam. Resources are also available on campus to help students needing academic support on this subject at the Center for Academic Success.

Course Structure & Weekly Breakdown

Week 1: Introduction to Relational Databases and SQL

- Overview of relational database concepts and database management systems (RDBMS).
- Introduction to SQL and its different command categories: DDL (Data Definition Language), DML (Data Manipulation Language), DQL (Data Query Language), DCL (Data Control Language), and TCL (Transaction Control Language).
- Hands-on practice with SQL commands such as SELECT, CREATE TABLE, INSERT, and UPDATE in PostgreSQL.
- **Lab Assignment:** Writing and executing basic SQL queries using PostgreSQL.

Week 2: Documentation, Business Needs, and Metadata

- Learn the importance of documenting data management practices and database structures.
- Identifying stakeholder needs and aligning database development with business objectives.
- Introduction to metadata standards (FGDC, ISO) and their role in geospatial data management.
- **Lab Assignment:** Creating a metadata file for a geospatial dataset and executing advanced SQL queries involving JOIN, GROUP BY, and ORDER BY.

Week 3: Database Design and Entity-Relationship Models (ERD)

- Introduction to database design principles and best practices for structuring relational databases.
- Understanding entity-relationship diagrams (ERDs) and their components: entities, attributes, relationships, and cardinality.
- The role of primary and foreign keys in enforcing referential integrity.
- **Lab Assignment:** Designing an ERD for a spatial database

Week 4: Normalization, Roles, and Privileges

- Understanding database redundancy and efficiency challenges.
- Applying normalization techniques (1NF, 2NF, 3NF) to a geospatial dataset.
- Identifying and resolving dependency issues in relational databases.
- Developing spatially enabled production and development environments (databases)
- Creating roles and assigning privileges
- **Lab Assignment:** Normalizing an unstructured GIS dataset and enforcing referential integrity with primary and foreign keys.

Week 5: SQL Data Modeling Review, Design, and SOP Development Recap

- Refine Existing Data Models
- Peer review and critique of data models from previous assignments.
- Enhancing database schema design based on collaborative feedback.
- **Lab Assignment:** Reviewing and Refining Existing Data Models

Week 6: Introduction to Spatial Databases and PostGIS

- Examine key differences and advantages of spatial databases compared to traditional relational databases.
- Explore PostGIS as an advanced tool for spatial data storage, manipulation, and analysis.
- Configure PostgreSQL environments to support spatial extensions effectively.
- Practice and configuration of PostGIS, creation of spatially-enabled tables, and manipulation of spatial data.
- **Lab Assignment:** Installation of PostGIS in PostgreSQL, creation of spatial tables, and insertion and validation of spatial datasets.

Week 7: Spatial Data Types & Functions in PostGIS

- Differentiate between key spatial data types (geometry and geography), understanding appropriate applications and limitations.
- Gain proficiency in importing and exporting spatial data formats including shapefiles, GeoJSON, and CSV with spatial components.

- Investigate essential PostGIS functions such as ST_Distance, ST_Intersects, ST_Buffer, and their usage in geospatial queries.
- Establish effective connections between PostGIS databases and ArcGIS Pro for data visualization and analysis.
- **Lab Assignment:** Import spatial data, conduct spatial queries using SQL, and visualize analysis outcomes within ArcGIS Pro.

Week 8: Geospatial Analysis Project – Developing an EV Charging Station Spatial Database

- Assess the role of spatial databases in site selection processes, focusing specifically on EV charging infrastructure deployment.
- Design effective workflows to address specific spatial research questions relevant to site suitability and optimization.
- Apply advanced spatial queries and analytical functions within PostGIS.
- Engage in discussions for final project Q&A, ensuring clarity in objectives and methodologies.
- **Project:** Conduct a comprehensive spatial analysis project, implementing learned spatial query techniques, database design, and documentation best practices.

Week 9: Indexing Spatial Data

- Evaluate the role of indexing for improving query performance in spatial databases.
- Explore and apply spatial indexing techniques, specifically GiST and R-tree indexing, and understand their respective advantages and application contexts.
- Analyze query execution and performance through practical application of EXPLAIN ANALYZE tools in PostgreSQL.
- Develop strategies to optimize spatial queries for large and complex datasets.

Week 10: Extract Transform Load (ETL) and Database Transactions

- Analyze the importance and operational roles of Extract, Transform, Load (ETL) processes within spatial data management.
- Implement ETL processes for efficient management and integration of diverse spatial datasets into spatial databases.
- Recognize and evaluate real-world scenarios demonstrating the application of spatial ETL in workflows leading to database and data warehouse integrations.
- Apply best practices for query optimization, transaction management, and handling large spatial datasets effectively.

Week 11 – 12: Geospatial Analysis Project – Developing a Real Estate Spatial Database

- Design, document, and execute an advanced ETL pipeline tailored specifically for real estate spatial data ingestion and transformation.
- Normalize real estate datasets into structured, relational database schemas to improve data consistency and query performance.
- Implement geospatial functionality in PostGIS, ensuring the integrity and accuracy of spatial data.
- Define, manage, and assign user roles and privileges within PostgreSQL using the Role-Based Access Control (RBAC) framework.
- Create metadata documentation and Standard Operating Procedures (SOPs) to maintain database sustainability, security, and long-term integrity.

Week 13: Student Presentations – Real Estate Spatial Database

- Student presentations outlining project outcomes, methodologies, and insights gained.
- Discussion of key findings, analytical results, and challenges encountered during database implementation.
- Live demonstration of spatial database structure and analytical capabilities.
- Group discussion focusing on lessons learned, best practices, and recommendations for future research.
- Instructor-led Q&A session evaluating student understanding and addressing remaining questions.

Week 14: Final Project Preparation

- Dedicated assistance session addressing student inquiries related to final project development.
- Clarification of concepts and skills from prior lessons to ensure readiness for final project implementation.
- Individual and group troubleshooting for spatial database setup, normalization, and ETL processes.
- Support with spatial queries, analytical techniques, and data visualization practices.
- Instructor availability for personalized guidance, feedback, and review of project workflows and documentation.

Week 15: Final Project Presentation

Presenting final database projects, demonstrating queries, visualizations, and documentation.

- **Lab Assignment:** Submitting final reports, project deliverables, and engaging in peer review discussions.

Appendix – University Addendums:

Students with Disabilities:

Accommodations for students with disabilities are provided for all students with a qualified disability under the Americans with Disabilities Act (ADA & ADAAA) and Section 504 of the Rehabilitation Act who request and are eligible for accommodations. The Office of Student Disability Services (SDS) is the UMBC department designated to coordinate accommodations that creates equal access for students when barriers to participation exist in University courses, programs, or activities.

If you have a documented disability and need to request academic accommodations in your courses, please refer to the SDS website at sds.umbc.edu for registration information and office procedures.

- SDS email: disAbility@umbc.edu
- SDS phone: 410-455-2459

If you will be using SDS approved accommodations in this class, please contact the instructor to discuss implementation of the accommodations. During remote instruction requirements due to COVID, communication and flexibility will be essential for success.

Sexual Assault, Sexual Harassment, and Gender Based Violence & Discrimination

UMBC Policy in addition to federal and state law (to include Title IX) prohibits discrimination and harassment on the basis of sex, sexual orientation, and gender identity in University programs and activities. Any student who is impacted by sexual harassment, sexual assault, domestic violence, dating violence, stalking, sexual exploitation, gender discrimination, pregnancy discrimination, gender-based harassment, or related retaliation should contact the University's Title IX Coordinator to make a report and/or access support and resources. The Title IX Coordinator can be reached at titleixcoordinator@umbc.edu or 410-455-1717.

You can access support and resources even if you do not want to take any further action. You will not be forced to file a formal complaint or police report. Please be aware that the University may take action on its own if essential to protect the safety of the community.

If you are interested in making a report, please use the Online Reporting/Referral Form. Please note that, if you report anonymously, the University's ability to respond will be limited.