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Construction of GIS Spatial Analysis Curriculum Framework for Human Geography Programs in Higher Education

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Abstract: This study aims to design a university-level course on GIS spatial analysis specifically tailored for human geography, addressing the current issues of excessively generalized course content (lacking disciplinary specificity) and an overemphasis on technical development while neglecting the integration of academic research and practical analysis. Through the integration of case-based teaching and practical exercises, the course design emphasizes the elucidation of fundamental operations, ensuring that students with no prior GIS knowledge can rapidly acquire the foundational skills and independently perform GIS spatial analysis relevant to human geography. The course content is structured around a "7+1+X" framework, covering essential topics such as GIS fundamentals, editing and operations of vector polygon and point data, network analysis, 3D spatial analysis, coordinate system transformations, and comprehensive spatial evaluation. This course is designed not only to equip students with the core principles and operational techniques of GIS spatial analysis but also to enhance their research capabilities and problem-solving skills, offering novel insights and references for GIS spatial analysis education in human geography.

1. Introduction

ArcGIS, developed by ESRI, is a comprehensive geographic information system (GIS) software platform that integrates various functionalities, including map creation, spatial data management, spatial analysis, geoprocessing, and the integration, publishing, and sharing of spatial information. ArcGIS offers a rich suite of tools and applications, and its robust functionality and flexibility make it one of the most widely utilized platforms in the field of geographic information science (GISc) [1]. Spatial analysis is a pivotal component of ArcGIS, providing essential technical support for fields such as geographic science, urban planning, environmental management, and resource conservation [2,3]. Consequently, many academic programs offer GIS spatial analysis courses based on ArcGIS software.

The application of GIS spatial analysis spans a wide range of disciplines, supporting various domains such as land management, public health, and environmental science [4–6]. However, in the context of human geography, teaching GIS spatial analysis to undergraduate and master's students with no prior GIS experience within a limited timeframe does not necessitate covering the full spectrum of GIS operations or knowledge. Instead, the course should focus on the specific spatial analysis techniques and operations most relevant to the discipline. Additionally, for students with no background in GIS, it is imperative to establish a solid foundation, enabling them to efficiently learn basic GIS operations and independently perform GIS spatial analyses. Currently, few GIS spatial analysis textbooks and curricula are tailored specifically for human geography students. Some curricula are overly comprehensive, while others are overly focused on technical proficiency. Furthermore, many GIS spatial analysis courses prioritize operational skills at the expense of integrating these skills with academic research and practical problem-solving scenarios, as noted in Walsh's course design [7]. Similar issues are reflected in the GIS course syllabi of several universities in the United States and Spain [8,9]. Therefore, there is an urgent need to develop a GIS spatial analysis course that is both application-oriented and specifically designed for human geography.

To address these concerns, this study designs a GIS spatial analysis course for human geography. The advantages of this course design include: its suitability for students with no prior GIS knowledge, facilitating rapid learning of fundamental operations; an emphasis on case-based teaching, supported by real-world data for replication; the integration of basic GIS operations with research-oriented applications to foster research and problem-solving skills; and its alignment with the specific needs of human geography, making it applicable to both undergraduate and graduate students in the field. Through this course design, we aim to provide new perspectives and guidelines for GIS spatial analysis education in human geography.

2. Instructional Design Philosophy and Training Objectives

2.1. Instructional Design Philosophy

The course has clearly defined, targeted teaching objectives, focusing on content most relevant to human geography. Given the vast and complex nature of GIS spatial analysis, not all topics are essential for human geography students. Within the constraints of limited teaching time, the course will focus on the most frequently utilized concepts and operations in the field, thereby facilitating more efficient learning.

The course adopts a case-based approach, integrating scientific research methodology to foster academic research capabilities through GIS spatial analysis. As GIS spatial analysis primarily involves practical applications, using real-world cases will enhance the effectiveness and engagement of the teaching process, stimulate students' interest, and improve their practical skills. The selected cases will be drawn from scientific research (e.g., published academic papers). Through case-based teaching, students will not only refine their GIS software skills but also develop research-oriented thinking and scientific inquiry capabilities.

The course is designed for students with no prior GIS knowledge, allowing them to quickly master basic operational skills. Human geography students often enter the course without prior exposure to GIS, making it crucial to design the curriculum to quickly establish a foundational understanding of GIS spatial analysis. The primary goal is to enable students to apply GIS spatial analysis techniques to address practical problems in human geography, urban, and regional studies. Therefore, the course design prioritizes foundational skills, with a significant portion of class time dedicated to teaching these essential operations. Given the time constraints, the course will emphasize clear, accessible explanations, enabling students to efficiently acquire fundamental skills and build a strong base for more advanced topics.

2.2. Course Training Objectives

The following objectives outline the key skills and competencies that students will develop through this program, equipping them with the knowledge and abilities to excel in the rapidly evolving field of GIS and its applications.

(1)Students should understand and master the fundamental principles and operations of GIS spatial analysis and utilize ArcGIS and other GIS software to conduct common spatial analyses in human geography, thereby addressing real-world issues in urban and regional studies and contributing to scientific research in the field.

(2)Students should proficiently use GIS spatial analysis software (e.g., ArcGIS) to organize, process, and analyze spatial data, possess data visualization capabilities, and apply quantitative analysis techniques to support practical problem-solving.

(3)The course aims to develop scientific research skills in human geography by leveraging GIS spatial analysis technologies. In urban and regional studies, it seeks to enhance students' digital, informational, and big data competencies while stimulating and guiding their research capabilities through case studies.

(4)Students should cultivate self-directed learning and a lifelong learning mindset, encouraging them to develop GIS spatial analysis thinking and apply it to theoretical and practical contexts, engage in self-reflection, optimize their knowledge structures, and meet the competencies required in the information age.

(5)The course fosters a sense of social responsibility, guiding students to recognize the impact of geographic information technology on society and the environment, promoting sustainable development, and adapting to the rapidly evolving GIS field. This will equip them with the professional skills and innovative mindset necessary for a responsible career in GIS.

(6)Students should develop effective communication and teamwork skills, enabling them to collaborate on group projects, contribute to research endeavors with a serious and diligent attitude, and enhance their communication capabilities with peers and the broader community.

3. Course Content Framework Design

Guided by the aforementioned instructional philosophy and training objectives, the course content is structured around a "7+1+X" framework. This includes seven core chapters: GIS fundamentals, editing and operations of polygon vector data, editing and operations of point vector data， network analysis, 3D spatial analysis, coordinate system transformations, and comprehensive spatial evaluation. These seven chapters form the backbone of the course, each consisting of several sections (Figure 1). The "1" in the "7+1+X" framework refers to an additional chapter that can be customized based on the specific focus and goals of different institutions or industry needs, such as the methodology for creating standardized GIS maps. The "X" represents experimental operations, which are designed to practice and extend the core content of the course, based on available class time. When designing experimental operations, it is recommended that they align closely with the seven core chapters, not simply as review exercises, but as integrative tasks that enhance students' ability to apply GIS software to solve real-world challenges and conduct scientific research.

The primary cases used in the course are as follows: Chapter 1 employs administrative boundary data from the Guangdong-Hong Kong-Macao Greater Bay Area; Chapter 2 utilizes housing rental data from the same region, emphasizing a research-oriented approach; Chapter 3 uses case studies from the urban area of Kunming, such as POI distribution and housing price prediction, focusing on developing students' ability to analyze urban issues; Chapter 4 explores inter-city network relationships using railway data from provincial capitals in China; Chapter 5 continues with case studies from Kunming, expanding students' ability to analyze spatial data from multiple dimensions; Chapter 6 integrates cases from Chapters 1–4, focusing on the development of students' foundational spatial analysis skills; Chapter 7 revisits cases from Kunming, encouraging students to apply comprehensive spatial analysis techniques for scientific research.

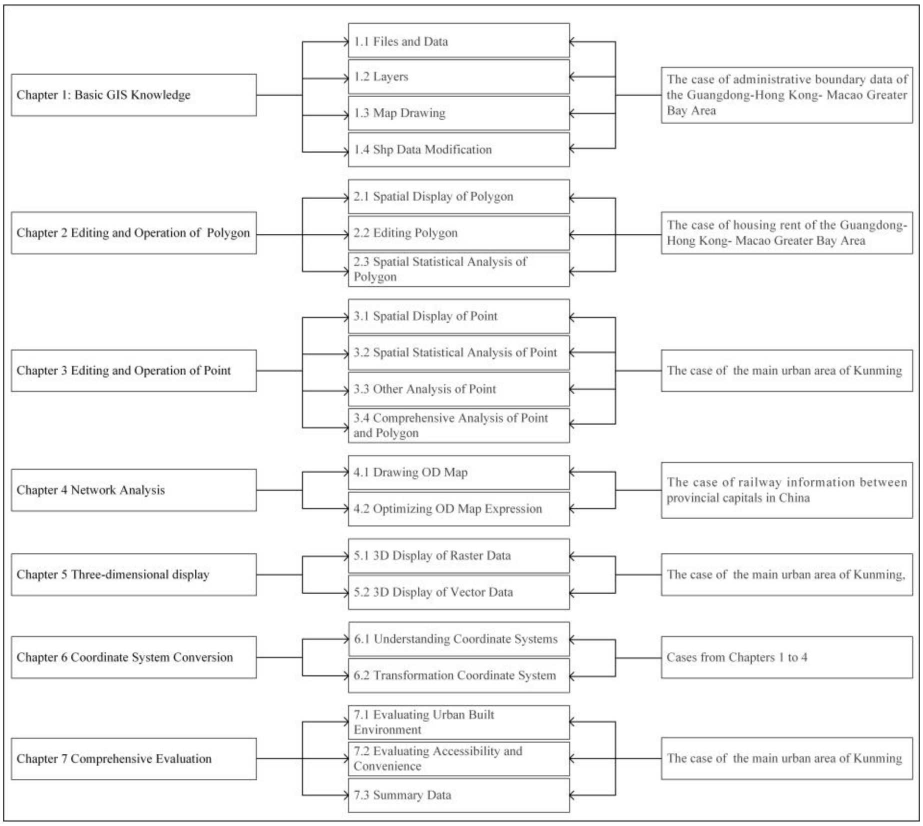

Figure 1: Suggested Core 7-Chapter Teaching Content System for GIS Spatial Analysis

4. GIS Operation Module Design

Based on the above content framework, 53 basic operation modules are designed across the seven chapters and 20 sections to support the core content of the course (Table 1).

Table 1: Main Operation Modules in the Course System.

Section	Operation Modules
1.1 Files and Data	① ArcMap interface composition; ② File and data composition; ③ Opening files and importing data; ④ Saving files and exporting data; ⑤ Copying files and data; ⑥ Data copying and renaming.
1.2 Layers	① Layer operations; ② Displaying different types of data layers.
1.3 Map Drawing	① Drawing maps in ArcMap and exporting; ② Combining Photoshop (PS) and ArcMap for map creation.
1.4 Shp Data Modification	① Shp data attribute table; ② Converting Shp data to Excel; ③ Linking Excel data with Shp data; ④ Modifying attribute table information.
2.1 Spatial Display of Polygon	① Color settings; ② Label settings; ③ Multi-layer boundary display.
2.2 Editing Polygon	① Editing polygon; ② Necessary operations after editing polygon.
2.3 Spatial Statistical Analysis of Polygon	① Global spatial autocorrelation analysis; ② Local spatial autocorrelation analysis; ③ Hotspot and Coldspot analysis.
3.1 Spatial Display of Point	① Point style and color; ② Hierarchical display of points; ③ Point labels.
3.2 Spatial Statistical Analysis of Point	① Average nearest neighbor analysis; ② Global spatial autocorrelation analysis; ③ Local spatial autocorrelation analysis; ④ Hotspot analysis.
3.3 Other Analysis of Point	① Kernel density analysis; ② Buffer analysis; ③ Trend surface analysis; ④ Interpolation analysis.
3.4 Comprehensive Analysis of Point and Polygon	① Creating grids; ② Counting Points within polygons; ③ Converting polygons to Points.
4.1 Drawing OD Map	① Drawing radial flow maps; ② Drawing network flow maps.
4.2 Optimizing OD Map Expression	① Optimizing network analysis maps; ② Detailed interpretation of network analysis results.
5.1 3D Display of Raster Data	① 3D display of kernel density; ② 3D display of interpolated maps.
5.2 3D Display of Vector Data	① 3D display of Point (e.g., residential housing price data); ② 3D display of polygons (e.g.,

	building data).
6.1 Understanding Coordinate Systems	① Map document coordinate system; ② Data coordinate system.
6.2 Transforming Coordinate Systems	① Transforming map document coordinate systems; ② Data projection.
7.1 Evaluating Urban Built Environment	① Building density; ② POI density; ③ Road density; ④ Functional diversity.
7.2 Evaluating Accessibility and Convenience	① Public transport accessibility evaluation; ② Office convenience evaluation.
7.3 Summary Data	① Summary of built environment, accessibility, and convenience; ② Comprehensive interpretation of evaluation results.

4.1. Basic Knowledge and Operations

4.1.1. Files and Data

In the file and data management section, the course begins with an introduction to the basic components of the ArcMap interface, including the catalog window, content list, view window, and toolbar. Focus is placed on GIS data types, especially map documents (.mxd format) and spatial data (e.g., Shapefile, raster data). The course will guide students through the process of opening existing map files, importing external data (e.g., Shapefile, CSV), and ensuring correct loading and display.

Additionally, students will learn how to save map documents, understand the difference between absolute and relative paths, and export data in various formats. The course will also cover how to copy, duplicate, and rename data files, which is crucial for maintaining standardized data management, avoiding redundancy, and enhancing management efficiency. These foundational skills will equip students with the necessary knowledge to handle spatial data management, setting the stage for more advanced spatial analysis.

4.1.2. Layers

In this section, basic layer operations in ArcMap are introduced, including managing the display, zooming, and moving of layers. Students will learn how to organize spatial data effectively by adjusting layer order and ensuring that different types of data are clearly visible.

The course will also cover how to set layer display effects based on data types. Different data types (e.g., points, lines, areas) require specific visual representations (e.g., different point symbols, line styles, or polygon colors and patterns). These settings will enhance the map's readability, ensuring that the spatial data is not only visually clear but also informative.

4.1.3. Map Drawing

In the map drawing section, the course introduces how to design and export maps in ArcMap. Students will learn how to select appropriate symbols, legends, and scale bars to create clear, effective maps. The course will guide students in setting up map layouts, including titles, legends, and labels, and exporting maps in formats such as JPG for presentation or printing.

Moreover, the course will explore how to combine ArcMap maps with Photoshop (PS) for further refinement and professional-quality map design. This integration enhances the visual appeal and quality of maps, making them suitable for high-standard presentations and publications.

4.1.4. Shp Data Modification

In the Shp data modification section, the course begins by introducing the structure of Shapefile attribute tables. Students will learn how to view, edit, and manage attribute data.

The course will cover converting Shapefile data into Excel format, which allows for easier data analysis and processing. Linking Excel data with Shapefile data will also be covered, providing students with enhanced flexibility in data handling. Finally, the section will introduce how to modify attribute table information, including editing field values and generating new data via calculated fields. These operations ensure that students can manage and modify spatial data efficiently, enabling them to conduct detailed spatial analysis.

4.2. Editing and Operations of Polygon

4.2.1. Spatial Display of Polygon

In the spatial display of polygons section, students will learn how to apply different color settings to polygons to visually distinguish between spatial features. The course will cover techniques for hierarchical display based on attribute values or ranges, enhancing map clarity.

Additionally, students will learn how to add labels to polygons, providing important attribute information such as area names, numbers, or other relevant data. This functionality improves map interactivity, making it easier to identify key areas on a map. The course will also teach how to display multiple layer boundaries on the same map, ensuring that the map remains clear even when representing different regions or datasets.

4.2.2. Editing Polygon

The polygon editing section will cover essential editing operations such as copying, pasting, deleting, merging, and splitting polygon objects. Students will learn how to accurately adjust spatial data to meet various analytical needs.

The course will also demonstrate how to recalculate the coordinates and area of polygons after editing to maintain data consistency and accuracy. This ensures that edited data remains aligned with the original datasets, reducing errors and maintaining precision.

4.2.3. Spatial Statistical Analysis of Polygon

The spatial statistical analysis of polygons is a crucial part of spatial analysis. Students will learn how to conduct global and local spatial autocorrelation analysis, which helps identify whether data exhibits spatial clustering or dispersion patterns.

Additionally, the course will cover hotspot and coldspot analysis, enabling students to identify regions with significantly high or low values. This analysis method is widely applied in fields like urban planning, environmental studies, and socio-economic research, helping students pinpoint areas that require special attention.

4.3. Editing and Operations of Point

4.3.1. Spatial Display of Point

In this section, we explore various ways to enhance the visual representation of point data in GIS. First, students will learn how to adjust point styles and colors to highlight key characteristics of the data, improving map visualization. This includes hierarchical display techniques, where point size and color are modified based on attribute values, making spatial distributions more intuitive and aiding in the identification of patterns. Additionally, we'll cover how to add labels to points, displaying key information such as location names or values for each point. This improves map functionality and allows for quick access to important data.

4.3.2. Spatial Statistical Analysis of Point

The spatial statistical analysis of points involves several key methods to help students understand spatial relationships and distribution patterns. Through Average Nearest Neighbor Analysis, students will assess whether points are clustered, dispersed, or randomly distributed, which is fundamental for understanding spatial relationships. Global Autocorrelation Analysis enables students to examine spatial distribution patterns across an entire region and identify trends in spatial clustering. In addition, Local Autocorrelation Analysis allows students to investigate local clustering or dispersion, enhancing their understanding of spatial heterogeneity. Finally, Hotspot Analysis teaches students how to identify spatial clusters where point values significantly deviate from the surrounding area, offering insights into areas of interest for further investigation.

4.3.3. Other Analysis of Point

This section introduces additional methods for analyzing point data that are commonly used in human geography. Students will explore Kernel Density Analysis to calculate the density of points across a space, which helps identify hotspot regions and distribution trends. Through Buffer Analysis, students will create buffers around points to assess impact ranges and conduct further spatial analysis. In Trend Surface Analysis, students will learn to construct trend surface models to identify spatial trends in the data, supporting geographic predictions. Finally, Interpolation Analysis enables students to estimate values at locations between points, allowing the creation of continuous spatial models that predict and analyze characteristics at unobserved locations.

4.3.4. Comprehensive Analysis of Point and Polygon

The comprehensive analysis of point and polygon data integrates both data types for a more complete spatial analysis. Students will first learn how to create grids to divide spatial data into smaller regions for detailed analysis. Then, they will learn how to count the number of points within polygons, conducting regional spatial statistical analyses. Finally, students will be taught how to convert polygons into point data, allowing for a flexible approach to different types of spatial analysis and data processing.

4.4. Network Analysis

4.4.1. OD Map Drawing

The course begins by teaching students how to generate radial flow maps using network analysis tools, visualizing the flow from a specified location to other destinations. This is essential for understanding spatial flow patterns, such as traffic or logistics. Later, students will learn to create complex network flow maps that combine multiple origins and destinations, enabling simulations of more intricate spatial flows and providing insights for solving real-world problems.

4.4.2. Optimizing OD Map Expression

Building on the OD map analysis, this section focuses on optimizing the visual expression of these maps. Students will learn to combine points, lines, and polygons, using various symbols, colors, and layer settings to improve the clarity and interpretability of flow maps. Optimized OD maps present network analysis results more intuitively, assisting in decision-making and analysis.

4.5. 3D Visualization

4.5.1. 3D Display of Raster Data

This section introduces the concept of transforming 2D raster data into 3D visualizations. Students will learn how to generate 3D kernel density and interpolated data maps, improving the clarity of spatial distributions. A specific focus will be placed on 3D housing price visualizations, which help reveal spatial trends and facilitate deeper data interpretation.

4.5.2. 3D Display of Vector Data

Students will also learn how to create 3D visualizations of vector data, such as housing price data, for enhanced spatial analysis. Additionally, building data will be converted into 3D models to help students visualize spatial layouts and relationships between buildings and their surroundings. This visualization method allows students to explore the complexity and dynamics of spatial data in three dimensions.

4.6. Coordinate System Transformation

4.6.1. Understanding Coordinate Systems

Coordinate systems are fundamental to spatial analysis. In this section, students will learn about commonly used coordinate systems and projection systems. They will gain an understanding of the differences between geographic and projected coordinate systems and learn how to select the appropriate system for different application scenarios. This knowledge ensures the accurate and effective handling of spatial data.

4.6.2. Transformation Coordinate System

Building on the previous section, students will learn how to transform coordinate systems within ArcMap to ensure data alignment. When datasets use different coordinate systems, students will be taught how to select the correct system and transform map documents for accurate spatial representation. This includes transforming projections between different systems, ensuring spatial relationships and geographic accuracy are maintained.

4.7. Comprehensive Evaluation

4.7.1. Evaluating Urban Built Environment

This section focuses on teaching students how to evaluate various aspects of the urban built environment using grid-based spatial analysis. Key topics include Building Density, which helps students understand the distribution of urban buildings and space utilization; POI (Points of Interest) Distribution, where students analyze the functional characteristics and density of service facilities; Road Density, which involves evaluating the accessibility and connectivity of urban transportation networks; and Functional Diversity, which assesses the mixed-use characteristics of urban areas. These analyses equip students with the tools needed to evaluate urban environments and make informed decisions for urban planning and spatial management.

4.7.2. Evaluating Accessibility and Convenience

The course will teach students how to assess urban accessibility and convenience based on grid units. Key evaluations include Public Transport Accessibility, where students will analyze the distribution and accessibility of public transport stations, and Office Convenience, which involves evaluating the layout and accessibility of office areas, including nearby services and transportation. These evaluations help students understand the spatial dynamics of transportation and services in urban areas, providing valuable insights for optimizing urban design.

4.7.3. Summary Data

The course will conclude by teaching students how to summarize and integrate evaluation data from various grids (e.g., building density, POI distribution, road density) to create comprehensive datasets. Students will learn how to use GIS tools to merge, clean, and statistically analyze this data, enabling effective comparison and supporting subsequent spatial analysis, such as pattern recognition and trend prediction.

5. Conclusion and Discussion

This study designs a GIS spatial analysis course tailored for human geography, addressing the current issues of overly generalized course content (lacking professional specificity) or a bias towards technical development, while neglecting the integration of academic research and practical analysis. The course framework adopts a "7+1+X" system, covering essential content such as GIS fundamentals, data editing and operations, network analysis, and 3D visualization. This ensures that students with no prior GIS knowledge can quickly master basic operations and independently conduct spatial analysis. Through a combination of case-based teaching and hands-on practice, students will not only master the basic theories and operational skills of GIS spatial analysis, but also significantly enhance their research and problem-solving capabilities.

Compared to traditional GIS spatial analysis course designs, this course offers new insights into teaching and research on GIS software operations in human geography, promoting the deep integration of GIS technology and human geography. The implementation of this course will further strengthen human geography students' ability to use GIS spatial analysis technology for comprehensive analysis and problem-solving, particularly in geographic spatial analysis and decision-making support. Future research can build on this foundation to further optimize course content, explore the impact of different teaching methods on student learning outcomes, and provide more refined solutions for GIS spatial analysis teaching in human geography. It is recommended that further research be conducted on course content and more effective teaching methods and cases be explored. Additionally, attention should be paid to the application of emerging technologies such as artificial intelligence and big data in GIS spatial analysis teaching, continuously optimizing course design to adapt to the rapidly changing technological environment and disciplinary needs. Through ongoing research and practical exploration, more scientifically grounded and effective support can be provided for GIS spatial analysis teaching in human geography.

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