

CERTIFICATE PROGRAM IN GEOGRAPHIC INFORMATION SCIENCE

Department of Geography
University of Utah
260 S. Central Campus Dr., Rm 270
Salt Lake City, UT 84112-9155
801-581-8218 (voice); 801-581-8219 (fax)
<http://www.geog.utah.edu/giscert/>
gis.certificate@geog.utah.edu

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SUMMARY

Geographic information science (GIS) involves the theory and methodology behind capturing, storing, analyzing and communicating digital information about the Earth and phenomena distributed on or near its surface. From its initial home in the discipline in geography, GIS has diffused to many fields concerned with geographic phenomena. Career opportunities in GIS continue to expand both locally and nationally. However, GIS software is becoming more sophisticated and increasingly embedded in broader information systems. The skill set required for a GIS career is shifting to include a combination of geography and computer science.

The certificate program proposed in this document addresses the changing demands for GIS education by providing strong integration of geography and computer science coursework. The certificate program also adopts a "multi-path" education philosophy to closely tailor students' educational experiences to their intended career path. Table 1 summarizes the four emphasis areas within the certificate program.

Table 1: Overview of GIS certificate program

Emphasis area	Targeted students	General requirements
Applied GIS	Undergraduate students in a non-computer science major	1/2000-level computer science: 3 or 4 hours 3000-level geography: 10 hours 5000-level geography: 11 hours Total: 24 or 25 hours
Remote Sensing	Undergraduate students in a non-computer science major	1/2000-level computer science: 3 or 4 hours 3000-level geography: 9 hours 5000-level geography: 9 hours Total: 21 or 22 hours
GIS application development	Undergraduate students in a non-computer science major	3/4/5000-level computer science: 13 hours 5000-level geography: 11 hours Total: 24 hours

	Graduate students in a non-computer science field	5000-level computer science: 7 hours 6000-level computer science: 6 hours 6000-level geography: 11 hours Total: 24 hours
GIS software design	Undergraduate computer science major	5000-level computer science: 6 hours 5000-level geography: 11 hours Additional upper division courses: 6 hours Total: 23 hours
	Graduate students in computer science	6000-level computer science: 6 hours 6000-level geography: 11 hours Additional graduate courses: 6 hours Total: 23 hours

1. OVERVIEW

Geographic information science (GIS) involves the theory and methodology of capturing, storing, analyzing and communicating digital information about the physical and socioeconomic phenomena distributed on or near the Earth's surface. During the last decade, GIS software has become very powerful, enabling the application of GIS tools in domains ranging from physical to social sciences and from basic research to applied problem solving. GIS professionals work in a variety of settings, including the private sector (e.g., logistics, market analysis, facilities management), public sector at the local, state and national levels and in GIS software firms.

The local and national job markets for GIS professionals are very strong and are not expected to weaken in the foreseeable future. The University of Utah's GIS education program has been successful in placing undergraduate and graduate students in these employment arenas. However, as the field matures our academic educational programs in GIS are becoming out of step with the skills required to solve the increasingly complex problems demanded by basic and applied science and planning.

This proposal outlines a certificate program in geographic information science that meets the evolving demand for GIS skills. Within the certificate program, students pursue one of four emphasis areas. The emphasis areas address varying needs for GIS professionals in academia, private and public sectors. Table 2 provides a brief overview of the educational objectives in each emphasis area.

Table 2: Educational objectives in GIS certificate program

Emphasis area	Objectives	Knowledge	Targeted students
Applied GIS	Professional trained in applying established GIS functions and analytical procedures	Knowledge of GIS theory and methodology, practical GIS software skills and basic scientific computing skills	Undergraduate non-computer science majors
Remote Sensing	Professional trained in applying remote sensing and GIS functions and analytical procedures to satellite and aerial remote sensing data	Knowledge of GIS theory, remote sensing theory, practical remote sensing and GIS software skills and basic scientific computing skills	Undergraduate non-computer science majors
GIS application development	Professional trained in designing and implementing enterprise GIS software systems and extending GIS functionality through custom applications	<i>Applied GIS</i> knowledge plus additional skills in GIS database design, system design and implementation, algorithm design and basic computer graphics & visualization	Undergraduate or graduate non-computer science majors
GIS software design	Computer scientists with domain-specific knowledge to support design and engineering of new GIS software	Strong knowledge of computer science with complementary knowledge of GIS application domains	Undergraduate or graduate computer science majors

2. PROGRAM DESCRIPTION

A student successfully completing the certificate program will be awarded a "Certificate in Geographic Information Science." Prior to entering the program, a student must choose one of four emphasis areas. This section describes the emphasis areas.

2.1. Emphasis in Applied GIS

2.1.1. Objectives

The outcome of this emphasis area is an individual trained in the skills required for solving common applications of GIS and related geocomputational techniques. This certificate combines skills and knowledge of three domains: i) substantive geography and basic geospatial analytical techniques from the undergraduate degree in geography; ii) GIS skills obtained through advanced GIS coursework, and; iii) basic software skills for solving computational problems in science and engineering.

2.1.2. Entrance requirements

Students entering this emphasis area must: i) be an undergraduate non-computer science major in good standing or a non-matriculated student with special permission; ii) receive approval from the GIS Certificate Program Committee.

2.1.3. Program requirements

C- or better in the following courses:

Course Number	Title	Credit Hours
CS 1000	Engineering Computing OR	3.0
CS 1020	Introduction to Programming in C++ OR	3.0
CS 1021	Introduction to Programming in Java OR	3.0
CS 1410	Introduction to Computer Science I OR	4.0
CS 2000	Introduction to Program Design in C	4.0
GEOG 3020	Geographical Analysis	3.0
GEOG 3040	Principles of Cartography	4.0
GEOG 3140	Introduction to GIS	3.0
GEOG 5140	Methods in GIS	4.0
GEOG 5150	Spatial Data Design for GIS	4.0
GEOG 5160	Spatial Modeling with GIS	3.0
Total Credit Hours		24 or 25

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee.

2.2. Emphasis in Remote Sensing

2.2.1. Objectives

The outcome of this emphasis area is an individual trained in the skills required for solving common applications of remote sensing and related geocomputational techniques. This certificate combines skills and knowledge of three domains: i) substantive geography and basic geospatial analytical techniques from the undergraduate degree in geography; ii) specialized remote sensing analysis skills, not available through the Applied GIS emphasis, obtained through advanced remote sensing coursework, iii) basic software skills for solving computational problems in science and engineering.

2.2.2. Entrance requirements

Students entering this emphasis area must: i) be an undergraduate non-computer science major in good standing or a non-matriculated student with special permission; ii) receive approval from the GIS Certificate Program Committee.

2.2.3. Program requirements

C- or better in the following courses:

Course Number	Title	Credit Hours
CS 1000	Engineering Computing OR	3.0
CS 1020	Introduction to Programming in C++ OR	3.0
CS 1021	Introduction to Programming in Java OR	3.0
CS 1410	Introduction to Computer Science I OR	4.0
CS 2000	Introduction to Program Design in C	4.0
GEOG 3020	Geographical Analysis	3.0
GEOG 3110	The Earth from Space: Remote Sensing of the Environment	3.0
GEOG 3140	Introduction to GIS	3.0
GEOG 5110	Environmental Analysis Through Remote Sensing	3.0
GEOG 5120	Environmental Optics	3.0
GEOG 5130	Advanced Remote Sensing Applications	3.0
Total Credit Hours		21 or 22

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee.

2.3. Emphasis in GIS Application Development

2.3.1. Objectives

The outcome of this emphasis area is an individual who commands the basic skills assumed in the applied GIS certificate plus the skills required for developing new GIS applications. Additional knowledge and skills include: i) software engineering tools; ii) knowledge of

algorithms and data structures; iii) data modeling and database design, and; iv) interface design or scientific visualization principles. These topics include both the foundation computer science techniques (obtained through CS coursework) as well as their applications in geographic science (obtained through geography coursework).

Undergraduate students successfully completing this emphasis area also receive a minor in computer science.

2.3.2. Undergraduate

2.3.2.1. Entrance requirements

Undergraduate students pursuing this emphasis must: i) be an undergraduate non-computer science major in good standing or a non-matriculated student with special permission; ii) receive a C- or better in the following pre-requisite courses or their equivalents:

- CS 1410 Introduction to Computer Science I; CS 2420 Introduction to Computer Science II; GEOG 3020 Geographical Analysis; GEOG 3040 Principles of Cartography; GEOG 3140 Introduction to GIS

iii) meet the entrance requirements for the undergraduate minor in computer science, and; iv) obtain approval from the GIS Certificate Program Committee.

2.3.2.2. Program requirements

C- or better in the following courses:

Course number	Course title	Credit hours
CS 3500	Software Practice	4.0
CS 4150	Algorithms	3.0
CS 5530	Database Systems	3.0
CS 5600	Introduction to Computer Graphics OR	3.0
CS 5630	Scientific Visualization	3.0
GEOG 5140	Methods in GIS	4.0
GEOG 5150	Spatial Data Design for GIS	4.0
GEOG 5160	Spatial Modeling with GIS	3.0
Total credit hours		24

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee.

2.3.3. Graduate

2.3.3.1. Entrance requirements

Graduate students pursuing this emphasis must: i) be a graduate student in a non-computer science program in good standing; ii) received a C- or better in the following pre-requisite courses or their equivalents during previous studies:

- CS 1410 Introduction to Computer Science I; CS 2420 Introduction to Computer Science II; GEOG 3020 Geographical Analysis; GEOG 3040 Principles of Cartography; GEOG 3140 Introduction to GIS

iii) obtain approval from the GIS Certificate Program Committee.

2.3.3.2. Program requirements

B- or better in the following courses:

Course number	Course title	Credit hours
CS 5010	Software Practice	4.0
CS 5150	Advanced Algorithms	3.0
CS 6530	Database Systems	3.0
CS 6610	Interactive Computer Graphics OR	3.0
CS 6630	Scientific Visualization	3.0
GEOG 6140	Methods in GIS	4.0
GEOG 6150	Spatial Database Design for GIS	4.0
GEOG 6160	Spatial Modeling with GIS	3.0
Total credit hours		24

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee.

2.4. Emphasis in GIS Software Design

2.4.1. Objectives

The objective of this emphasis area is a computer scientist well-versed in the unique problems involved in capturing, storing, analyzing and communicating digital geospatial data. The

computer science degree program provides the background in foundational and advanced software design skills while the supplementary geography coursework provides foundational and advanced skills in geographic information science. This background provides the basis for advancing the design and implementation of software for representing and analyzing digital geospatial data.

2.4.2. Undergraduate

2.4.2.1. Entrance requirements

Undergraduate students pursuing this emphasis must: i) be an undergraduate computer science major in good standing or a non-matriculated student with special permission; ii) receive a C- or better in the following prerequisite courses or their equivalents:

- GEOG 3020 Geographical Analysis; GEOG 3140 Introduction to GIS; GEOG 3040 Principles of Cartography

iii) obtain approval from the GIS Certificate Program Committee.

2.4.2.2. Program requirements

C- or better in the following courses:

Course number	Course title	Credit hours
CS 5530	Database systems	3.0
CS 5600	Introduction to Computer Graphics OR	3.0
CS 5630	Scientific Visualization	3.0
GEOG 5140	Methods in GIS	4.0
GEOG 5150	Spatial Data Design for GIS	4.0
GEOG 5160	Spatial Modeling with GIS	3.0
Two additional upper division courses in geography or a related field		6.0
Total credit hours		23

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee.

The additional upper division (3000 or above) courses should be in a substantive subfield of geography or a related discipline. This must be approved in advance by the GIS Certificate Program Committee.

2.4.3. Graduate

2.4.3.1. Entrance requirements

Graduate students pursuing this emphasis must: i) be a graduate computer science major in good standing; ii) receive a C- or better in the following courses or their equivalents during previous studies:

- GEOG 3020 Geographical Analysis; GEOG 3140 Introduction to GIS; GEOG 3040 Principles of Cartography

iii) obtain approval from the GIS Certificate Program Committee.

2.4.2.2. Program requirements

B- or better in the following courses:

Course number	Course title	Credit hours
CS 6530	Database systems	3.0
CS 6610	Interactive Computer Graphics OR	3.0
CS 6630	Scientific Visualization	3.0
GEOG 6140	Methods in GIS	4.0
GEOG 6150	Spatial Database Design for GIS	4.0
GEOG 6160	Spatial Modeling with GIS	3.0
Two additional graduate courses in geography or a related discipline		6.0
Total credit hours		23

Note: *Course substitutions* are not allowed for "Program Requirements" courses in this or any GIS Certificate emphasis area. Course substitutions are allowed for "Entrance Requirements" courses at the discretion of the GIS Certificate Program Committee

The additional graduate (6000 or above) courses should be in a substantive subfield of geography or a related discipline. This must be approved in advance by the GIS Certificate Program Committee.

2.5. Course Descriptions

Note: Some courses have additional prerequisites external to the certificate program. Please pay close attention.

2.5.1. Computer Science

CS 1000 Engineering Computing (Credits: 3) Co-requisite: CS 1010, MATH 1210. Course taught: Fall, Spring. (Course is currently under review and long-term status is uncertain.)

Introduction to programming principles and engineering problem solving via computational means using MATLAB (during the first half of the semester) and C (during the second half of the semester). Decomposition of programs into data representation, functions, and control structures. Clean programming practices are emphasized. The MATLAB portion of the course focuses on the implementation of physically-based models, data visualization via plotting and selected numerical techniques. The C portion of the course introduces basic syntax and special features of the language for engineering implementations.

CS 1020 Introduction to Programming in C++ (Credits: 3) Course not currently being offered.

An introduction to essential programming concepts using C++. Laboratory practice required.

CS 1021 Introduction to Programming in Java (Credits: 3) Course taught: Fall.

An introduction to essential programming concepts using Java. Laboratory practice emphasizes object-oriented techniques and web-based application design

CS 1410 Introduction to Computer Science I (Credits: 4) Co-requisite: CS 1010, MATH 1210. Course taught: Fall, Spring.

The first course required for students intending to major in computer science. Introduction to the engineering and mathematical skills required to effectively program computers, and to the range of issues confronted by computer scientists. Roles of procedural and data abstraction in decomposing programs into manageable pieces. Introduction to object-oriented programming. Extensive programming exercises that involve the application of elementary software engineering techniques.

CS 2000 Introduction to Programming Design in C (Credits: 4) Co-requisite: CS 1010, MATH 1210. Course taught: Fall.

Introduction to essential programming concepts using C. Decomposition of programs into functional units; control structures; fundamental data structures of C; recursion; dynamic memory management; low-level programming. Some exposure to C++. Laboratory practice. (Intended for non-CS/CE majors).

CS 3500/5010 Software Practice (Credits: 4) Prerequisites: CS 2420. Course taught: Fall. CS 5010 is for graduate students from departments other than Computer Science.

Practical exposure to the process of creating large software systems, including requirements specifications, design, implementation, testing, and maintenance. Emphasis on software process, software tools (debuggers, profilers, source code repositories, test harnesses), software engineering techniques (time management, code, and documentation standards, source code management, object-oriented analysis and design), and team development practice. Much of the work will be in groups and will involve modifying preexisting software systems.

CS 4150 Algorithms (Credits: 3) Prerequisites: CS 2100, 2420. Course taught: Spring.

Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CS 2420. Balanced trees, heaps, hash labels, string matching, graph algorithms, external sorting and searching. Dynamic programming, exhaustive search. Space and time complexity, derivation and solution of recurrence relations, complexity hierarchies, reducibility, NP completeness. Laboratory practice.

CS 5150/6150 Advanced Algorithms (Credits: 3) Prerequisites: CS 4150. Course taught: Fall, every year.

Design and analysis of algorithms. Greedy algorithms, dynamic programming, divide and conquer. Asymptotic analysis and recurrence relations. Graph algorithms and network flows. Computational complexity and intractability. NP-hardness and beyond. Approximation algorithms.

CS 5530/6530 Database Systems (Credits: 3) Prerequisites: CS 3500. Course taught: Fall. Note: 2009-10 course will be taught in Spring.

Representing information about real world enterprises using important data models including the entity-relationship, relational and object-oriented approaches. Database design criteria, including normalization and integrity constraints. Implementation techniques using commercial database management system software. Selected advanced topics such as distributed, temporal, active, and multi-media databases.

CS 5600 Introduction to Computer Graphics (Credits: 3) Prerequisites: CS 3500, MATH 2250. Course taught: Spring.

Basic display techniques, display devices, and graphics systems. Homogeneous coordinates, transformations, and clipping. Introduction to lighting models. Introduction to raster graphics and hidden-surface removal.

CS 5610/6610 Interactive Computer Graphics (Credits: 3) Prerequisite: CS 5600. Course taught: Fall.

Interactive 3D computer graphics, polygonal representations of 3-D objects. Interactive lighting models. Introduction to interactive texture mapping, shadow generation, image-based techniques such as stencils, hidden-line removal, and silhouette edges. Introduction to image-based rendering, global illumination, and volume rendering.

CS 5630/6630 Scientific Visualization (Credits: 3) Prerequisites: CS 3505; CS 3200 or CS 6210 or MATH 5600. Course taught: Fall.

Introduction to the techniques and tools needed for the visual display of data. Students will explore many aspects of visualization, using a "from concepts to results" format. The course begins with an overview of the important issues involved in visualization, continues through an overview of graphics tools relating to visualization, and ends with instruction in the utilization and customization of a variety of scientific visualization software packages.

2.5.2. Geography

GEOG 3020 Geographical Analysis (Credits: 3) Prerequisite: MATH 1030, 1050 or equivalent. Course taught: Spring, every year.

Emphasizes the spatial point of view and presents techniques of spatial analysis applicable to all fields of geography. Introduction to the use of multiple correlation and regression techniques in geographic research with special attention addressing problems in the use of these techniques with spatial data.

GEOG 3040 Principles of Cartography (Credits: 4). Prerequisite: MATH 1030, 1050 or equivalent. Course taught: Fall, every year.

Fundamental principles of cartography including perception, visualization, topographic and thematic map interpretation, field mapping techniques (including GPS), and creating computer-based maps in weekly labs. Principles include direction, scale, grids, projections, and spatial transformations, spatial data analysis, data manipulation decisions, color theory and application, and principles of cartographic design and critical evaluation.

GEOG 3110 The Earth from Space: Remote Sensing of the Environment (Credits: 3). Course taught: Fall, every year.

Over the past decade there has been an extraordinary increase in the availability of remote sensing images of Earth. Many people are now familiar with programs like Google Earth. The explosion in the availability of remote sensing data has coincided with a growing number of remote sensing applications. Remote sensing data are now used in anthropology, civil engineering, environmental sciences, geography, geology, hydrology, natural resource assessment, meteorology, and urban planning. This course adopts an interdisciplinary approach applicable to those fields, examining remote sensing theory, techniques, and applications. The course explores the physical basis for remote sensing and remote sensing technologies that use sunlight, infrared radiation, radar, and lasers. Five lab exercises give "hands-on" experience with real remote sensing data.

GEOG 3140 Introduction to GIS (Credits: 3) Prerequisite: MATH 1030, 1050 or equivalent. Course taught: Fall, every year.

A recent increase in the use of digital geographic information in many fields has created the need for experts with the knowledge to use this information to society's benefit. Geographers, engineers, environmental scientists, planners, social scientists, computer scientists and many other professionals will encounter digital geographic information in some form in their future careers. This course introduces students to issues that arise in using this information in scientific and decision-making arenas. Topics include: applications of geographic information; modeling geographic reality; spatial data collection; geographic analysis; accuracy and uncertainty; visualization; and legal, economic, and ethical issues associated with the use of geographic information.

GEOG 5110 Environmental Analysis Through Remote Sensing (Credits: 3) Prerequisite: GEOG 3110. Course taught: Spring, every year.

High-resolution multispectral data, coupled with expanding computing power and increasingly sophisticated image processing software, provides a large set of quantitative, graphic and science visualization tools for solving science-based environmental problems using remote sensing data. The theory and application of image-processing techniques such as: data corrections, enhancements, transformations, and classification are aimed at specific environmental problems in the natural and human domains. Hands-on experience is gained through image processing laboratory techniques, field-based measurements and real-world science projects.

GEOG 5120 Environmental Optics (Credits: 3) Prerequisites: GEOG 3110; MATH 1060 or PHYS 1010 or equivalencies; or instructor consent. Course taught: Spring, every year.

The physical principles that determine how light and matter interact are essential to understanding remote sensing and Earth's energy budget. This course explores the complex interactions of electromagnetic radiation with the Earth's surface and atmosphere from a quantitative perspective. The physical foundations of visible, infrared, and microwave remote sensing are addressed using both theory and laboratory measurements. Theoretical explanations of reflection, absorption, and transmission of electromagnetic radiation are used to explore practical applications of environmental optics in remote sensing, climate modeling, and everyday phenomena.

GEOG 5130 Advanced Remote Sensing Applications (Credits: 3) Prerequisite: GEOG 5110. Course taught: Fall, every year.

Project-based science applications; project objectives, selection of alternative procedures, planning, execution, evaluation, and publication.

GEOG 5140/6140 Methods in GIS (Credits: 4) Prerequisite: GEOG 3140 (except for graduate students).

Course taught: Spring, every year. GEOG 5140 meets with GEOG 6140; graduate students should enroll in GEOG 6140 and will be held to higher standards and/or more work.

This course explores the practice of using a geographic information system (GIS) to support geographic inquiry and decision making. Students will strengthen their technical knowledge of the common tasks that a geographic analyst faces in applying a GIS to a variety of spatial problems. The lab sections offer an opportunity to gain hands-on experience using a leading commercial GIS to complete a series of real-world projects.

GEOG 5150/6150 Spatial Database Design for GIS (Credits: 4) Prerequisite: GEOG 5140/6140. Course taught: Fall, every year. Graduate students should enroll in GEOG 6150 and will be held to higher standards and/or more work.

Digital spatial data is widespread due to the global positioning system (GPS), satellite-based remote sensing, intelligent transportation systems and other geographic information technologies. Spatial data is important and useful due to geographic information systems (GIS) and other spatial applications such as Internet map serving and location-based services. However, spatial data involves complex objects and relationships that cannot be accommodated easily by standard database management systems. This course reviews the fundamentals of database design and data management to support GIS and other spatial applications. Topics include modeling spatial data, spatial database design, spatial query languages, spatial database storage and indexing, and spatial query optimization.

GEOG 5160/6160 Spatial Modeling with GIS (Credits: 3) Prerequisite: GEOG 5140/6140. Course taught: Spring, every year. Graduate students should enroll in GEOG 6160 and will be held to higher standards and/or more work.

The power to model complex environmental systems in a geo-spatial framework is one of the great assets of GIS. This course places the fundamental operations and software of spatial analysis and GIS in a modeling framework. The course addresses advanced concepts and techniques in map algebra, cartographic modeling and descriptive and predictive spatial modeling. The course has both lecture and required lab components.