Design And Assessment Of An Undergraduate GIS Curriculum

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Abstract

The field of geospatial information science (GIS) draws upon a diverse group of information technologies and scientific disciplines. This diversity makes GIS an exciting and popular discipline but at the same time makes the design of a comprehensive undergraduate curriculum a challenging exercise. Since its inception, spatially related concepts, courses and majors have been a part of the cadet educational experience at the United States Military Academy, West Point. From its early beginnings in surveying, this experience has evolved into an academic major focusing on spatial information science and technology. This paper will describe the evolution of this curriculum and the recent redesign and assessment of the program within the constraints of the liberal arts education requirements at the Academy.

1. Geospatial Information Science As A Discipline

Geospatial Information Science (GISc) is a modern discipline focusing on the integration of evolving technologies dealing with the acquisition, management and analysis of spatial information. Historically components of GISc have resided in a diverse set of academic disciplines. Geographers have always focused on the spatial aspects of the cultural and physical landscape and have been instrumental in the development of digital cartographic and geographic information systems. Computer scientists are largely responsible for the database management systems that are ubiquitous in today's society. Without these systems the geographic information systems that provide us with the opportunity to analyze and visualize spatial data would not exist as we know them today. Engineers, primarily Civil and Electrical, have furthered the science of geodesy and have developed modern acquisition systems such as digital photogrammetric systems, LIDAR, modern surveying systems and the Global Positioning System. These technological advances and the underlying scientific principles that govern their use provide the spatial data that feed geographic information systems and other spatial data visualization software systems.

Academically, each of these disciplines focuses on different aspects of GISc. Geographers concentrate on the analysis and display of spatial information. Numerous geography departments within the United States allow students to receive a minor in Geographic Information Systems (GIS). Certificate programs in GIS have recently become very popular and are offered in geography departments at several universities. These minor and certificate programs in GIS typically require students to complete courses in remote sensing, cartography and geographic information systems. Computer Science programs often do not distinguish between spatial and non-spatial data but

instead focus on how to efficiently manage information within the scope of information technology. Civil Engineering departments have long been the home of surveying programs, courses in geodesy and aerial photogrammetry (as opposed to aerial photo interpretation).

Over the past ten years departments/programs have been created with the intent to integrate each of these aspects of geospatial information under the umbrella of a single academic unit. Most of these efforts have occurred within Colleges of Engineering. Geomatics or Geomatics Engineering Departments now exist at the University of Alaska-Anchorage, the University of Florida, Fresno State University, the Ohio State University and Purdue University. Each of these programs focus on the engineering aspects of geospatial information but include courses that cross over each of the academic disciplines discussed previously. Undergraduate degrees in these programs require a diverse set of course work to include: geodesy, geodetic & control surveying, photogrammetry, geographic information systems, cadastral principles, remote sensing, map projections, boundary law, digital cartography, and adjustment computations. Elective courses in the earth sciences and computer sciences are also often required.

2. Geospatial Information Science At The United States Military Academy

2.1 History

Aspects of the mapping sciences have been an important part of the educational experience of cadets at the United States Military Academy (USMA) since its inception in 1802. In 1803 Congress approved a teaching position in drawing at the USMA that was initially filled by a Frenchman named Francis Masson. Shortly thereafter the Department of Drawing was created. Early courses taught in this department included technical drawing and military topography focusing on the accurate representation of the earth's surface. Technical Surveying was also taught at the USMA during this time but in a different academic department. Beginning in 1876 technical drawing of machinery using mathematical principles took on a more prominent position within the Department of Drawing. However, topographical drawing continued to be taught as well. The late 1800s through the early 1900s saw a marked evolution in the direction of the Department of Drawing. This period saw the focus of the curriculum shift from technical drawing to surveying, plane and descriptive geometry, cartography, linear and isometric projections, and topographic sketching.

By 1940 military topography and landscape characterization had become the important components of the department. In 1942 the department was renamed the Department of Military Topography & Graphics. The curriculum of the department now focused on military sketching for mapping, map and air photo interpretation, surveying, graphics and mechanical drawing. During the 1950s saw a reduction in the amount of vocational style training within the department. Courses in astronomy and geology were added. In 1960 the name of the department was changed once again to the Department of Earth, Space, and Graphic Sciences reflecting the emphasis in the department on engineering principles and the environment. Several new courses were added to the curriculum: physical

geography, digital computers, engineering fundamentals, astronomy-astronautics, and geology. The department was divided into two groups: 1) Engineering Fundamentals; and, 2) Environment. The Engineering Fundamentals group taught courses in surveying, descriptive geometry, topographical drawing, engineering drawing and graphical mathematics.

In the 1970s courses in automated cartography and geographic information systems were added to the department in an attempt to keep pace with modern technology. Increased emphasis was also place on courses in computer science. With the increasing importance of computers within society and the Army the department underwent another transformation and was renamed the Department of Geography & Computer Science in 1979. In the early 1980s the Computer Graphics Laboratory was created with funding from the Defense Mapping Agency to generate terrain visualization and analysis software for the Army. This was the precursor to the current Geospatial Sciences Laboratory that exists within the department today. The 1980s also saw the development of an academic program within the department entitled Mapping, Charting and Geodesy (MC&G) and offering an undergraduate Batchelor of Science Degree in MC&G (Geography). Courses offered in this program included computer cartography, aerial photogrammetry, remote sensing, geographic information systems, surveying and astronomy. In 1988 the computer science program left the department and joined with electrical engineering. This move resulted in the department being renamed the Department of Geography. In 1990 the department went through its last transformation and is now named the Department of Geography & Environmental Engineering. The MC&G was renamed the Geospatial Information Science program in 2000 and the Batchelor of Science degree was re-designated B.S. in Geospatial Information Science. This transformation also saw the addition of two new courses in advanced remote sensing and advanced geographic information systems and the removal of the course in astronomy.

2.2 Existing Curriculum

A minimum of forty courses are required for graduation from the USMA, forty-three if pursuing a degree in one of the engineering disciplines. This equates to approximately 120 semester units. Additionally, qualified cadets have the option of enrolling in an honors program requiring three additional courses in their major. Twenty-seven of these forty courses are part of the core curriculum that every cadet is required complete. During the freshman (plebe) and sophomore (yearling) years each cadet takes the same courses. Cadets declare a major during their sophomore year but generally do not begin to take courses in that program until their junior (cow) year.

Each cadet is also required to take a three course engineering sequence that focuses on one of the engineering majors offered at the USMA (civil, mechanical, electrical, environmental, computer science, nuclear, and systems). All cadets are required to enroll in some type of cultural immersion course that exposes them to global cultures. Within the Dept. of Geography & Environmental Engineering this requirement is met through a course in human geography. This leaves nine courses to be taken within the selected major. However, an integrative experience course is also required for each major

reducing the number of discipline foundation courses to eight. The integrative experience for a major in Geospatial Information Science is a course in Military Geography.

Cadets majoring in Geospatial Information Science are required to take six core courses in the discipline as well as two free electives. The six core courses required for the major, as well as brief course descriptions, are listed below.

EV377 REMOTE SENSING

SCOPE

Remote Sensing is learning about something without touching it--the most obvious example being the use of satellites to study the Earth. EV377, a techniques course applicable to both the humanities and engineering, studies how and what types of information can be carried by the electromagnetic spectrum. Students enjoy a wide range of practical exercises which introduce them to several remote sensing systems to include conventional and color infrared photography, multispectral scanners, satellite imagery, thermal infrared, and radar. The capstone exercise offers each student the opportunity to perform real-time automated image classification using satellite data on his/her own micro-computer. The course focus is on applying remotely sensed data to solve current problems.

LESSONS: 30 @ 55 min (2.500 Att/wk) **LABS:** 10 @ 55 min

EV378 CARTOGRAPHY

SCOPE

Cartography teaches the principles of cartographic communication and enables the student to apply map design principles along with computer mapping techniques to solve contemporary problems in geography, economics, international relations, and applied sciences. Cadets will study the basic cartographic design process and use mapping and analysis software in the geographic sciences laboratory to produce topographic and thematic maps. A final course design project presents the opportunity for the cadets to demonstrate their ability to synthesize sound mapping principles.

LESSONS: 23 @ 55 min (2.500 Att/wk) **LABS:** 17 @ 120 min

EV398 GEOG INFORMATION SYSTEMS

SCOPE

Geographic information systems are hardware/software systems that permit the input, storage, retrieval, manipulation, analysis, and display of geocoded data. Used by environmentalists, engineers, land-use planners, architects, managers of large land holdings, and the military, these highly-intricate "decision support" systems assist managers in answering important "what if" questions. Using digitizers and microcomputers students will build a geocoded database and solve "real-world" problems.

LESSONS: 30 @ 55 min (2.500 Att/wk) **LABS:** 10 @ 55 min

EV477 ADVANCED REMOTE SENSING

SCOPE

This course examines advanced remote sensing theory and digital image processing techniques suitable for the processing of remotely sensed data. Emphasis is on the processing and analysis of state-of-the-art high spatial and spectral resolution data gathered by airborne and satellite sensors. Topics covered include geometric and radiometric image rectification, registration and resampling techniques, image enhancements, data merging, image segmentation, and automated contextual feature extraction. A wide range of practical exercises and in-class laboratory assignments provides hands-on experience with a variety of remotely sensed imagery ranging from multi-spectral to hyper-spectral data. The course culminates with a capstone term project that allows cadets to apply digital image processing skills to a scientific problem.

LESSONS: 25 @ 55 min (2.500 Att/wk) **LABS:** 15 @ 55 min

EV498 ADV GEOGRAPHIC INFORMATION SYS

SCOPE

This course examines the analytical methods used in Geographic Information systems (GIS) and provides cadets with a clear understanding of the theoretical/conceptual aspects of algorithms found in GIS software. Lectures focus on the underlying mathematical basis for widely used spatial analytical techniques. Among the topics covered are neighborhood operations, map transformation, spatial interpolation, terrain analysis, network analysis, spatial overlay, fuzzy sets, neural networks, and expert systems. In-class practical exercises and laboratory assignments compliment the lectures by providing hands-on experience with a variety of advanced analytical techniques. The course culminates with a capstone term project that allows cadets to identify a scientific problem, formulate a hypothesis, use GIS to solve the problem, and then present the results of their analysis.

LESSONS: 30 @ 55 min (2.500 Att/wk) **LABS:** 10 @ 55 min

Additionally, cadets must take either Photogrammetry or Principles of Surveying.

EV379 PHOTOGRAMMETRY

SCOPE

Photogrammetry, the art and science of making accurate measurements on photographs, is an important and fundamental discipline concerned with civilian and military mapping. Students, applying simple geometric principles to the photograph, determine object identity, size, spatial relationship, and position. An abundance of practical exercises, involving the use of sophisticated equipment, provide the opportunity to apply the fundamentals while arriving at solutions to real-world problems. An interesting field trip to a local mapping organization vividly displays how all these techniques may be blended to produce maps in the commercial business world.

LESSONS: 30 @ 55 min (2.500 Att/wk) **LABS:** 10 @ 55 min

EV380 PRINCIPLES OF SURVEYING

SCOPE

A framework for understanding and applying practical surveying methods is developed. Consideration of error theory provides practical knowledge concerning the concepts of precision and accuracy and yields understanding of the probabilistic nature of measurements.

LESSONS: 25 @ 55 min (2.500 Att/wk) **LABS:** 15 @ 115 min

Two free elective courses are selected from the list below. Note that both the course in Photogrammetry and Principles of Surveying are included in this list. Cadets are highly encouraged to select one of these courses as an elective depending on which one was chosen as a required course.

Course #	Course Title	Course #	Course Title
EV 300	Environmental Science	*or*	
EV 371	Geography of Russia	EV 399A	Geology Field Course
EV 372	Geography of Asia	EV 388B	Geomorphology
EV 373	Geography of Latin America	EV 389B	Climatology
EV 374	Geography of the Middle East & Africa	EV 389H	Meteorology and Air Pollution
EV 379	Photogrammetry	EV 390B	Urban Geography
EV 380	Surveying	EV 391A	Land Use Planning and Management
EV 384	Geography of North America	EV 391B	Environmental Geology
EV386	Geography of Europe	EV 481	Water Resources Planning and Design
EV 388A	Physical Geology	EV489A	Advanced Individual Study In Geospatial Information Science

3. Program Assessment

Assessment of the GISc curriculum was broken down into three phases: 1) an internal program review; 2) benchmarking against GISc curricula at other universities; and, 3) an outside expert panel review of the curriculum. At the present time the first two phases of the assessment process have been completed.

3.1 Internal Program Review

Phase one consisted of a critical review of existing courses and lessons within courses as they relate to the goal of the program. Particular emphasis was placed on 1) the relevance of individual lessons given recent advances in technology, and 2) the identification of redundant topics and lessons between courses. This necessitated a lesson by lesson review of each course.

Several instances of lessons discussing outdated topics were identified. Most of these instances were found in the Photogrammetry and Principles of Surveying courses. For example, the course in Photogrammetry included two lessons dealing with the use of parallax bars to measure parallax, a lesson focusing on aerial films and wet laboratory development procedures, and another lesson discussing analog stereo plotters. Given recent advances in softcopy photogrammetric systems and digital aerial cameras it was decided to remove these lessons from the course. This in turn provided an opportunity to add lessons, practical exercises and laboratory assignments that would capitalize on recently acquired digital photogrammetric workstations. Similarly, outdated lessons dealing with such topics as taping were targeted for removal from the course in Principles of Surveying. These lessons were replaced with discussions and field exercises regarding the application of global positioning system technologies to surveying. Two lessons addressing the visual interpretation of geologic terrain features were removed from the Introduction to Remote Sensing course. While these lessons certainly fell within the scope of the course as they related to image interpretation, it was felt that they would be more appropriate in a geomorphology course. Removal of these lessons allowed for the expansion of the digital image processing component in this course.

Similar or nearly identical lessons were found to exist in some of the courses offered in the program. For example, three lessons were devoted to photo interpretation in the course in Photogrammetry. These same topics were covered extensively in the Introduction to Remote Sensing course to include graded laboratory assignments. Thus, it was decided that these lessons could be removed from the course in Photogrammetry and be replaced with additional lessons focusing on digital photogrammetry. Discussions on supervised and unsupervised classification techniques were found in both the Introduction to Remote Sensing and Advanced Remote Sensing courses, although in different levels of complexity. The expansion of the digital image processing component of the Introduction to Remote Sensing course, discussed previously, allowed for this material to be taken out of the advanced course. These were replaced with new material, exercises and graded laboratory assignments on contextual classifiers. Overlap between the courses in Cartography and Introduction to Geographic Information Systems were also identified. These dealt primarily with methodologies and techniques associated with the acquisition of spatial information in a digital format. It was felt that these topics were more germane to the Introduction to Geographic Information Systems course and were therefore removed from the course in Cartography. These lessons were replaced with lessons on the fundamentals of graphic design.

As a result of the internal review it was felt that the courses offered in the program were more focused and current with regards to existing and emerging technologies.

3.2 Benchmarking Against Other Academic Curricula

The USMA Geospatial Information Science curriculum was compared to those at six other universities in the United States: University of Alaska – Anchorage, Ohio State University, Fresno State University, Purdue University, and the University of Florida.

Each of these universities have Geomatics or Geomatics Engineering programs integrated within Colleges of Engineering.

Common core academic stems were found to exist between these programs. Requirements for two years of higher level mathematics to include Calculus & Analytic Geometry along with Probability & Statistics were consistent within each of the programs. Each of the five programs required a minimum of one year of Physics while all required one semester of Chemistry. A minimum of two courses in computer science/programming were found within each of the five curricula. However, it should be noted that additional courses in computer science/programming were to be found in lists of recommended electives for each of the programs. Additionally, programming was often imbedded in courses within the major, often in cartography or computer aided mapping courses. Each of the programs also stipulated that one or two fundamentals of engineering courses be taken. Most of the programs also required that some type of earth science elective be taken. Courses in the humanities that make up many core general education curricula such as history, literature, writing, and philosophy were also part of each curriculum.

The Geospatial Information Science program at the USMA was found to mirror the requirements discussed above. Every cadet at the USMA must complete two years of higher level mathematics to include Calculus and Probability & Statistics. Two semesters of Physics and Chemistry are also required. Two courses in Information Technology (computer science/programming) must be taken by each cadet as well. A three course engineering sequence must also be completed in order to graduate. Additionally, the USMA core curriculum requires three semesters of english, four semesters of history as well as courses in law, economics, sociology and philosophy.

Common threads were also observed within the discipline specific courses required for graduation in each of the five programs evaluated. Each of the programs required at least one course in each of the following areas: geomatics, geodesy, digital mapping/cartography, remote sensing, map projections, adjustment computations, cadastral principles, photogrammetry, surveying, and geographic information systems. Often more than one course in one or more or these topic areas were required. Additionally, each of the programs evaluated required the completion of a senior project to meet the requirements for graduation. Twelve to 16 discipline specific courses were needed for completion of a typical undergraduate program in these curricula.

The most significant difference between the Geospatial Information Science curriculum at the USMA and the five university programs evaluated is in the breadth and depth of discipline specific courses. As discussed previously seven discipline specific courses are offered within the USMA Geospatial Information Science program. This is significantly less than the 12 to 16 required at each of the five programs that the USMA program is being benchmarked against. The most obvious shortfalls in terms of fundamental courses offered within the discipline are the lack of an introduction to geomatics course, a basic geodesy course, and a course dealing with cadastral concepts and map projections. A cadet could take an additional four to eight course beyond the minimum forty required for

graduation while at the USMA. Therefore, in theory additional courses in these topics could be offered and required of cadets for graduation. Currently, however, the policy in place at the USMA regarding the creation of new courses is that for a new course to be offered an existing course must be removed from the academy catalog of courses. Thus, the addition of new courses is problematic. Important topics dealing with geodesy, cadastral concepts and map projections have been integrated into the seven existing courses offered within the Geospatial Information Science program. For example, map projections are discussed in both the cartography and geographic information systems courses. Fundamentals of geodesy and cadastral concepts are covered in the courses in photogrammetry and surveying.

Most of the programs evaluated offered at least two courses in each subject area and some times three. Constraints with regards to the generation of new courses at the USMA has also impacted the ability to match the depth of courses offered within the programs at other universities. It is highly unlikely that the opportunity will occur to add one or two courses let alone the five or six needed to be comparable with these other programs.

3.3 External Expert Panel Review

The final component of the three phase assessment process involves the review of the program by an external panel made up of experts in the discipline. This phase of the assessment has not been completed. Experts from both academia and industry are being solicited for membership on the review panel. These individuals will be provided with materials describing each course in depth as well as briefings by individual instructors. The panel will also be given the opportunity to meet with students at each class level. At the conclusion of the review the panel will be required to provide a report on their findings as well as make a presentation to the Geospatial Information Science faculty, the head of the department and the Dean of the Academy.

4. **Conclusions And Recommendations**

The Geospatial Information Science curriculum at the USMA was found to provide the fundamental course work needed for a student majoring in this discipline. Deficiencies in the depth of knowledge covered were identified and had been previously recognized by the faculty of the program. Following the completion of the program by an external expert panel all of the information gained from the review process will be integrated into a final evaluation report. Changes to the curriculum based upon these findings will be recommended for implementation to the USMA curriculum committee. Approved changes by the curriculum committee will then be implemented.