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Integration of GIS in Civil Engineering Curriculum

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Abstract

Geographical Information System (GIS) has traditionally been used in geography and natural resources curricula in the United States. The University of Hartford is among a few institutions that early on recognized the impact of the new GIS technology on Civil Engineering programs. GIS technology is rapidly expanding into most areas of Civil Engineering. As part of a major curriculum revision the Civil and Environmental Engineering (CEE) Department at the University of Hartford revamped its two credit Surveying course to a new four credit course entitled Introduction to Surveying and Geographical System. In addition, the department introduced a senior/graduate level course entitled Advanced GIS. An ILI grant from the National Sciences Foundation enhanced the capabilities of the department in terms of new computers and software. This enabled GIS principles to be incorporated in different fields of civil engineering such as Transportation Engineering, Water Resources Engineering, Geotechnical Engineering, Water Quality Engineering, Groundwater Hydrology, and Engineering Hydrology.

I. Introduction

Geographic Information Systems, perhaps a marriage between database and digital mapping, has been in use since the 1950s. With the advent of high-speed computers and advances in digital mapping technology, it is possible to manipulate large amounts of data in a very short period of time. The technology is extremely versatile and helpful to civil engineers.

Increased accuracy in Global Positioning System (GPS) equipment has opened another area where GIS and GPS can be used hand to hand to aid the civil engineering profession. However, civil engineers have not taken advantage of the technology until very recently. Not only, has the civil engineering profession been a latecomer in adopting the technology, the civil engineering curriculum across the United States has been extremely inadequate in the field of GIS and GPS. One possible reason may be the elimination of surveying courses from many civil engineering curricula. Many civil engineering programs in the United States do not have a required dedicated course in surveying, GIS or GPS at all, some have an elective course in a geography or natural resource program, some teach it in a graduate civil engineering course, and some incorporate GIS in other courses. Very few institutions have actually incorporated GIS in their curriculum. A survey of the department heads through the ASCE dhc (department head council) server showed that only about 10 percent of the responding departments had a required course in their civil engineering curriculum.

The CEE Department at the University of Hartford embarked upon a major revision of its curriculum, known as the CE 2000, in the late 90s. The Department early on recognized that GIS was rapidly expanding into most areas of Civil Engineering and that it was necessary to revise the Civil Engineering program to reflect the impact of the new GIS technology on the profession. This led to CE 2000, our extensively revised curriculum tailored to meets the needs of graduating engineers in the early 21st century. An ILI grant from the National Science Foundation (NSF) enabled the CEE Department to establish a student centered multimedia laboratory, with a GIS component as its centerpiece.

At about the same time, the State of Connecticut, through the University of Connecticut, established an on-line library of digital geospatial data called the Map and Geographic Information Center (MAGIC). The digital data which is in the public domain and available on the World Wide Web include[1]

- Named streets with address ranges (1:100,000 TIGER, by county and town, vector data)
- Census geography (i.e. block group, tract, 1:100,000 TIGER, by county and town, vector data)
- 1970, 1980, & 1990 decennial census data (for town and tracts, by county, tabular data)
- Population data (1:24,000 USCensus, tract and town, vector data)
- Housing data (1:24,000 USCensus, tract and town, vector data)
- Surficial Material (1:24,000 ConnDEP, 7.5 min. quad and town, vector data)
- Drainage Basin (1:24,000 ConnDEP, 7.5 min. quad and town, vector data)
- Soils (1:24,000 SCS, 7.5 min. quad and town, vector data)
- Soils (1:250,000 SCS, state, vector data)
- Hydrography (1:24,000 ConnDEP, 7.5 min. quad and town, vector data)
- Land Use/Land Cover (1:24,000 ConnDEP, satellite imagery derived, town, vector data)
- Roads (1:24,000 ConnDEP, 7.5 min. quad and town, vector data)
- Roads (1:250,000 ConnDEP, state, vector data)
- Streets (1:100,000 USCensus, county and town, vector data)
- Town Boundary (1:24,000 USGS, 7.5 min. quad and town, vector data)
- Town Road Units (1:24,000 ConnDOT, town, vector data)
- Tics (1:24,000 ConnDEP, 7.5 min. quad and town, vector data)
- National Wetlands Inventory (1:24,000 FWA, 7.5 min. quad, vector data)

- Digital Orthophotographs (1:12,000 USGS; quarter 7.5 min. quad, raster data)
- Digital Raster Graphics (1:24,000 USGS; 7.5 min. quad, raster data)

The NSF ILI grant, along with the GIS resources available through MAGIC, allowed the CEE Department to follow through on its resolve to incorporate GIS into as many courses as possible.

II. Integration of GIS in the curriculum

The first course that was affected in major way was an introductory two credit Surveying course. This was the first course (CE 250) in which GIS was introduced. Revision in this course involved the introduction, at all levels of instruction, of geospatial analysis. Geospatial analysis involves applying the technologies of geographic information systems (GIS), the global position system (GPS), and remote sensing to solve engineering analysis, design, and environmental problems. As part of the curriculum revision, the two credit traditional surveying course was expanded to four credits by the addition of GIS and GPS. With this course placed in the first semester of the sophomore year, it serves as the introduction to Geospatial Analysis. Skills learned serve as a basis for upper level courses such as Geotechnical Engineering, Water Quality Engineering, and Water Resources Engineering. The course also serves as an introduction to Civil Engineering as it is the first departmental course encountered by CEE students. It therefore plays a role in retention.

One of the major problems in teaching a course that relies heavily on computer systems, is the need to identify the software and matching computer hardware. With help from local professionals, we determined that the ArcView[2]/PC system for GIS, and the Trimble[3] GPS system would be most advantageous for instruction and for the students' future needs. The hardware and software were purchased under the NSF/ILI grant "A Multi-media Student Centered Approach to Geographical Information Systems (GIS) Laboratory Instruction".

The expanded part of the new course was designed primarily to be web based[4]. For the GPS portion, the Trimble tutorial was well suited for our purposed and served as a text. We developed homework questions based on the tutorial, and laboratory exercises that introduced the GPS equipment. All labs and homework were submitted via e-mail from the course web site. The final GPS lab compares differentially corrected data to that of a known point, and differences compared to manufacturers specifications as to accuracy.

For the GIS portion of the course, a text prepared by Environmental Systems Research Institute (ESRI) – "Getting to Know ArcView"[5], was used as a lab text. We developed questions for each lab, to be submitted via e-mail from the web site. A standard text[6] was also used to introduce GIS material and supply homework questions, the answers to which were submitted by e-mail. The goal at the end of the lab and homework exercises was to introduce basic concepts such as map coordinate systems, different kinds of spatial data, etc, and how to use the ArcView software. To test their knowledge of GIS principles, the students, in a final project, were asked to find a suitable site for a commuter station along a proposed light rail right-of-way. Since there is no "canned" data, as is present in their lab exercises, students learned to download data from different sources, and perform GIS exercises that lead to potential solutions based on siting criteria. Formal maps and a written report were the final product. At the end of the course, students were expected to be able to perform standard GIS analyses using the ArcView software package, and to apply what they had learned to other courses.

Geotechnical Engineering I (CE 330), is a junior level course in which the principles of soil mechanics are taught. The course has a laboratory component also. The reconnaissance part of field investigation for any geotechnical engineering project includes a review of the Soil Survey maps developed by the Natural Resources Conservation Service (NRCS), formerly known as the USDA Soil Conservation Service. These maps are available on the MAGIC site in digital form. Students download the maps using their GIS software and use them for preliminary soil investigation for their class projects.

As part of the Water Quality Engineering (CE 420) course, students are required to work on a laboratory project that is sponsored by a water utility or environmental consulting firm. For one project, students used current drogues to study the hydrodynamics of a reservoir. The location of the current drogues with time were determined using a hand held GPS unit. The data was then down loaded into GIS software along with a map of the reservoir. By plotting the movement of the current drogues directly on a map of the reservoir, it clearly showed how the velocity of the current varied at different locations in the reservoir.

The Engineering Hydrology (CE 523) course is a senior / graduate level elective course. In this course, students are introduced to spatial hydrology. While GIS is not suitable for time-series data, it is very effective for the spatial characterization of a watershed. This requires the students to learn how to use ArcView Spatial Analyst Extension, which is not taught in the introductory GIS course. Topics covered include the representation of watershed features in raster and vector format and the delineation of a watershed using digital elevation models. In class demonstrations and exercises are used to illustrate these topics. Students are then required to do a group project at the end of the course.

A groundwater model for an area in Enfield in Northern Connecticut was developed as part of an independent study project. The selected area in Connecticut had been known to have very high concentrations of Ethylene dibromide (EDB) in the groundwater. The EPA has established a drinking water standard for EBD of 0.05 parts per billion. Drinking water wells with concentrations of EDB greater than 0.05 ppb, require either a bottled water substitute or the use of an approved filtration system. The well examined in this study had a concentration that averaged over 10ppb for the last 5 years. Geographical Information Systems (GIS) technology was integrated with Ground Water Modeling Systems (GMS) to develop a model that predicted the EDB migration, groundwater direction and elevation. The results obtained from this model compared reasonably well with the field values. The integration of GIS and groundwater modeling almost completely eliminates the more laborious method of entering values on a cell by cell basis. In yet another independent study project, GIS technology was used to devise a pavement management system for the Town of Bloomfield in Connecticut, utilizing the digital maps from the MAGIC site and the relevant data from the Connecticut Department of Transportation.

In addition to the use of GIS in academic coursework, our students have used GIS technology in several community projects. In one such project, civil engineering students mapped out the Town of Manchester Historic District into different architectural styles. In a similar project another group of students created a land use map combing a field survey database and AutoCAD drawings to create a map reflecting different types of land use in the City of Hartford.

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