Designing Geographic Information System Courses in the IS Curriculum

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Abstract

The use of geographic information system (GIS) has been growing tremendously in many areas of application. The low cost of hardware and software, along with the relative ease of access to data on the internet, fueled the proliferation. When IS/IT practices in business begin to seek for a competitive edge in the intelligent use of information, GIS skills and technologies offer new ways of using information, such as those in spatial and topological data analysis. In this paper, we share the design of two GIS courses to expand our IS curriculum: one at the undergraduate level and the other at the graduate level. The courses emphasize the value of GIS applications, while building on the fundamental model of the GIS architecture as the necessary foundation. These include the structures of data and files. We also briefly survey the equipment and sources of data needed to teach the courses effectively. The costs involved in setting up to teach the GIS courses are relatively low.

Keywords: geographic information system, IS curriculum, business information intelligence

1. INTRODUCTION

When asked to define the essential skills and functional areas of study in IT, the field professionals are quick to point to a functional area identified as Business Information Intelligence (Caputo 2004). While IS education has grown through the years, it has always focused on the values in business, from short term to long term. When basic IT skills and foundational understanding become required fundamental training for all IT professionals, businesses seek skills that will bring a competitive advantage in the market place. The area identified as Business Information Intelligence represents such a highly desirable asset or skill set. Caputo et al also pointed out, that it is not a single-entity skill set, but the ability to fuse corporate goals and objectives with relevant and powerful technological processes, citing (Smith 2001).

IS education must therefore keep track of and be updated to cover new developing technologies. Geographic information system (GIS) is a relatively new tool introduced into the IS/IT environment (Boasson 2004), even though it has a long track record in computer cartography. Fueled by the lowering cost for hardware and software, and the easy access to data sources through the internet, use of GIS is growing tremendously in many areas of application, from environmental engineering to business planning to disaster management. Skills in using GIS are fast becoming a most favored asset in the IS/IT industry. According to an article titled

"Mapping Opportunities" in the magazine *Nature*, the U.S. Dept of Labor has identified GIS technology as one of the three most important emerging and evolving fields, along with nanotechnology and biotechnology, and that the GIS market is estimated to grow to $30 billion by 2005 (Gewin 2004). The time to include GIS technologies into the IS curriculum is due.

GIS has been defined in number of ways, and Boasson et al cited several interesting definitions, noting different views of GIS. Boasson went on to highlight a few GIS applications, from simple classroom questions to intricate market analysis (Boasson 2004). This paper discusses a few application areas of GIS, and presents the design of two GIS courses being added into the IS curriculum at Robert Morris University, one at the undergraduate level, and the other at the graduate level. The syllabuses illustrate how the course design places the emphasis on the value of GIS applications, but also covers the basic GIS architectural model. The fundamental understanding of GIS architecture and a good grasp of the data and file structures will build up the foundation for GIS skills, along with the need for data exchange on the internet. The paper also discusses the necessary equipment to set up a GIS lab for these course, showing that the cost of adding the GIS courses to the IS curriculum is relatively low.

2. GIS APPLICATIONS

GIS application has gone far beyond the traditional areas of environmental planning. Consider building the business case for a gourmet coffee shop at a certain location of an urban area. We can look into the distribution of per capital annual income of the people there. The U.S. Census Bureau divides up urban areas into blocks and provides the census data as averages in each block as public information. Figure 1 shows these blocks of a certain urban area. Using the GIS, we can specify the condition "PCI00 > 47000" just like that in an SQL statement to select those blocks with average per capital annual income more than $47,000 (the mnemonic PCI00 for the average per capita annual income in the block). In figure 2, the GIS high-lighted these selected blocks. It becomes quite clear in this case where are the appropriate locations for the new gourmet coffee shop, as we observe that most of the north west section and a cluster toward the east side are indicated. Further, we can also identify the locations of competitor coffee shops on the same map to analyze the competition.

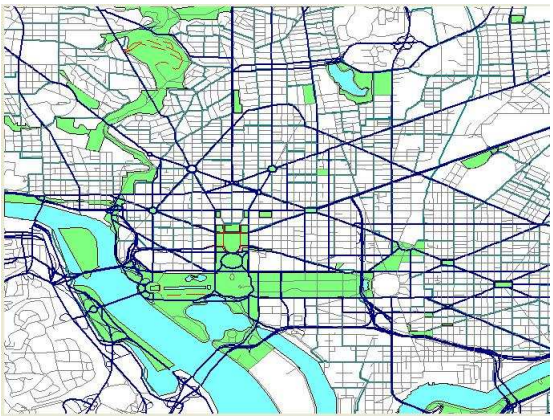

Fig.1 Census blocks of a certain urban area

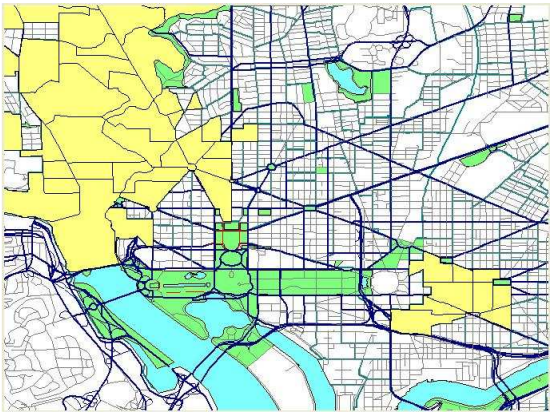

Fig.2 Census blocks with average per capita annual income more than $47,000.

Figure 3 shows the GIS display of the major road ways in another city. With information about the volume of traffic on each of the road ways, we can plan the locations of fire stations to make sure that emergency vehicles can arrive at an accident scene within certain time limit while minimizing the number of stations needed in order to control the total cost. This application goes beyond conventional spatial analysis and applies network analysis. Using the GIS, we can then work out many "what if" cases in our analysis. The information is also very valuable in dispatching emergency teams on emergency vehicles. This simple quick response from the GIS can become crucial in the situation of terrorist attack.

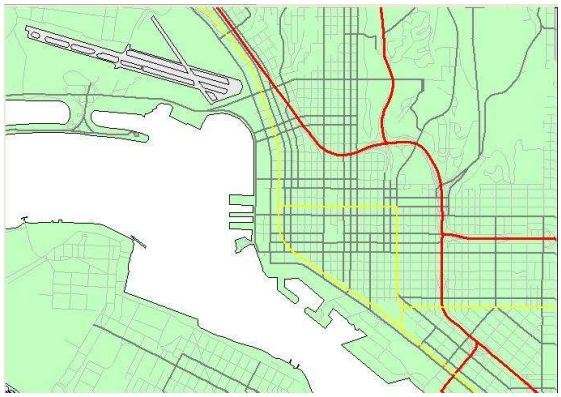

Fig.3 Major roadways of a certain city

3. TWO GIS COURSES

The Department of Computer Information Systems (CIS) at Robert Morris University in Pittsburgh, Pennsylvania offers both undergraduate and graduate programs in Information Systems. The department is in the process of adding to its IS curriculum two GIS courses, one at the undergraduate and another at the graduate level, both as advanced electives in the current IS programs. The undergraduate course titled "**Introduction to GIS**" provides the students an overview of GIS and its use. The course introduces GIS from its roots in computer cartography and covers the issues of map representation, including data and file structures. Building on an understanding of the architectural model, the students will get a glimpse of the wide range of GIS applications. The graduate course titled "**GIS: Tutorial and Applications**" develops the architectural model of understanding GIS through tutorials, and followed by the applications of spatial analysis. In both cases, students will acquire hands-on experience in projects using GIS on a personal computer. In the following, we list the coverage of the topics in a semester of 15 weeks, for the two courses, respectively. Each topic is listed with the duration in the number of weeks, along with the textbook or references chosen at this point.

Introduction to GIS

Table 1 shows the topics covered in Introduction to Geographic Information System. The textbook referred to is *Getting Started with Geographic Information Systems – 4th edition* (Clarke 2003). The course primarily goes through the whole book. As in traditional cartography, GIS organizes information over an area in different map layers. While the student should get used to the basic functionality features of the GIS in the Introduction, the important point to understand the different map layers. Each map layer captures the information about each geographical feature (point, line, or area) along with attribute information. The user can choose any combination of layers for display or the focus of attention in the GIS. The next topic Map on the Computer digs deeper into how the GIS organizes the data for the map layers. File and data structures for GIS are covered. In Acquisition of Map Data, the student will have to put into practice their understanding. This includes conversion of data and file formats when acquiring data from other sources on the internet, and also the use of GIS to interactively enter data. The main focus of Geo-database and Spatial Analysis is GIS application. The student will begin to see how the GIS is a database management system with a special interface and capability for spatial data. These GIS functionalities form the core capabilities for GIS applications. The next topic of Making maps with GIS then wraps up with how to present the results of using GIS for information analysis. Basic map making is necessary to produce such a report. Picking a GIS begins a review of what the course has covered by identifying key system issues in the GIS. The students should be challenged to critically think about what they understand about the GIS architectural model. The final topic GIS Application case study is the time when students to work on a final project on selected GIS applications. The chosen textbook includes information and data sources for five different projects.

GIS: Tutorial and Applications

Table 2 shows the topics covered in Geographic Information System: Tutorial and Applications. The textbook and reference books chosen are: Getting Started with Geographic Information Systems 4th edition (Clarke 2003), Beyond Maps: GIS Decision Making in Local Government (O'Looney 2000), Modeling Our World: the ESRI Guide to Geodatabase Design (Zeiler 2000), Cartographic Design using ArcView GIS (Madej 2000), and The ESRI Guide to GIS Analysis Vol.1: Geographic Patterns and Relationships (Mitchell 1999).

The Introduction of this graduate GIS course begins with the same exercises. But it moves with a much faster pace. The next topic Fundamentals of Map Design covers the basics of data and file structures in the GIS, but also begins to deal with the map making features so that the students will get into the principles of map design. In GIS Processes and Outputs, the students will use the GIS as an information processing center for spatial data. The student will practice acquiring map data as well as report generation with output maps. The next topic, File Formats and Geodatabases, will cover the details of data and file structures, for the purpose of getting into GIS applications. Students then begin to be exposed to statistical analysis capabilities of the GIS, like that of a database management system equipped with statistics tools and a 2D visual interface for map display. Then we move into spatial data handling beginning with Spatial Data Input. The data can be imported from aerial photos, existing raster maps, or keyboard entries. The process bring the students to exercises requiring a good understanding of data structures for the map features of points, lines, and polygons. An interesting feature is in using the GIS to look up an address. Geocoding and Address Matching covers that. The capstone to all these is then spatial analysis using the GIS. In Spatial Data Processing and Spatial Analysis, students will be using the GIS for problem solving in application projects.

The primary value of the GIS courses is in the applications. That is appropriate for GIS courses in the IS curriculum. However, a conceptual understanding of the basic GIS architecture is fundamental to the intelligent application of using the GIS. Therefore, we spend a substantial portion of the time on basic GIS functionalities, with a focus to build up that conceptual understanding of the GIS architectural model. At the undergraduate level, the **Introduction to GIS** course also brings out the system architectural model explicitly under the topic "Picking a GIS". The students will then get a glimpse of the range of GIS applications in the final projects for the class. Sample projects are also made available in the textbook (Clarke 2004). At the graduate level, the **GIS: Tutorial and Applications** course goes through the basic GIS functionalities in a sequence of tutorials with a much faster pace, leading up to applications in statistical and spatial analysis. We expect the graduate students to grasp an understanding of the system architectural model through the tutorials. The students will also be expected to complete a more advanced project in GIS applications, making specific use of spatial analysis.

4. LAB EQUIPMENT AND DATA SOURCES

Traditionally, use of GIS is a costly proposition because of the expensive equipment necessary to run a GIS, with both hardware and software. In the past couple of decades, the cost of these equipment has gone down tremendously. This is at least part of the reason for the proliferation of GIS use in many application areas. In a school with an existing IS program, most likely a laboratory already runs a local area network of personal computers with reasonably high performance. Granted the capabilities of personal computers today, much of the traditionally needed equipment is no longer necessary in a general purpose GIS lab today.

First, there is also no need for a large flat-bed plotter unless it is necessary to made large maps on paper. Normally, there is no such need. Even for the occasional need of a large map, one can conveniently bring or send the file to a shop with that capability (such as Kinko). Second, there is also no need for digitizers. To import the data from a printed map, we can display a scanned digital image of the map as the background on the display screen, the GIS as well as many software tools today will allow us to use the mouse to indicate specific points to import map data on display digitally (Clarke 2003, p.205). In other words, the interactive graphical use of screen and mouse functionally obviates the use of a flat-bed digitizer. A good scanner can be useful, but that again can be shared with other shops or labs for its occasional use.

We are then left to be concerned only about the appropriate screen size, and the amount of memory and disk storage on the computers. Depending on the GIS software of choice, the requirements may be slightly different. Yet the 17" screen should be sufficient for most general use; the 15" screen would be a bit small and somewhat inconvenient for use. For most GIS software, a smaller screen does not prohibit its use. The

19" screen will be more than sufficient for most course project applications. The RAM storage requirement is also dependent of the choice of GIS software. But for most systems running on Microsoft Windows (assuming Windows XP), the reasonable RAM requirement would usually be 256M, without performance degradation for smaller RAM size until some minimal requirement. Disk storage is quite inexpensive today, and can generally be provided by a server via the network. This simply means that most IS schools would have laboratories ready to run GIS software.

For commercial GIS software, a well-known leader is ArcGIS available from ESRI (Environmental Science Research Institute, web site at http://www.esri.com.). ArcGIS is a collection of many GIS tools. At the time of writing of this article, the author checked the educational price of ArcView – a major component of ArcGIS – is $1000 for 25 seats in a local area network. The other components can be added on an as needed basis, while ArcReader for viewing only is freely available from ESRI. There is also GRASS (Geographic Resources Analysis Support System), a complete GIS software freely available on the web (at http://grass.itc.it) from Free Software/Open Source foundation, under the GNU general public license.

The web also provided public access to much useful data today. This will be very useful for student projects. The list in table 3 includes several of these source – the organization name and the web site. An introductory textbook such as (Clarke 2003) would provide much more elaborate description for each of the sources.

5. SUMMARY

With GIS use growing tremendously in many different application areas, and useful data quite readily available for use, the time is ripe to include GIS technologies and skills into the IS curriculum. It is also strategic since the IS/IT market place is eagerly seeking skills that bring out more intelligent use of information in business. We presented and discussed the design of our two GIS courses being added to the current IS curriculum, at the Robert Morris University. One course, **Introduction to GIS** is added to the undergraduate curriculum, and the other course, **GIS: Tutorial and Application**, to the graduate curriculum. In both cases, the emphasis is on GIS applications. We also attempt to build up a conceptual understanding of the GIS architectural model through exercises with the basic GIS functionalities. This means lots of projects for hands-on experience. In the undergraduate course, we also sum up the GIS model explicitly. In the graduate course, the pace is much faster, leading to more advanced applications. Spatial analysis and data visualization in mapping are the functionalities not found in database management systems. We also briefly surveyed the laboratory equipment needed to teach the GIS courses effectively. We concluded that the GIS courses can be included in an existing IS curriculum with relatively low cost.

6. REFERENCES

Boasson, E., V. Boasson and W.J. Tastle (2004) "A New Tool in IS Management: Geographic Information Systems." Proceedings of ISECON 2004, Newport, RI, v.21., SS.3124.

Caputo, D., P. Kovacs and J. Turchek (2004) "Defining the Essential Skill and Functional Areas of Study in IT as Measured by a Survey of Field Professionals." Proceedings of ISECON 2004, Newport, RI, v.21, SS.2215.

Clarke, K.C. (2003) Getting Started with Geographic Information Systems, 4th edition, Prentice Hall.

Gewin, V. (2004) "Mapping Opportunities." Nature, Vol.427, pp.376-377.

Madej, E. (2000) Cartographic Design using ArcView GIS, ESRI Press, Redlands, CA.

Mitchell, A. (1999) The ESRI Guide to GIS Analysis Vol.1: Geographic Patterns and Relationships, ESRI Press, Redlands, CA.

O'Looney, J. (2000) Beyond Maps: GIS Decision Making in Local Government, ESRI Press, Redlands, CA.

Smith, D.F. et al (2001) The Educational Needs: Southwestern Pennsylvania Industry Cluster Analysis, Pittsburgh Technology Council, Pittsburgh, PA.

Zeiler, M. (2000) Modeling Our World: the ESRI Guide to Geodatabase Design, ESRI Press, Redlands, CA.

Topic	Duration	Textbook Reference
Introduction to using GIS - basic GIS: map layers - identify, search, label map features - geo-database and attribute information	1 week	Chapters 1 & 2
Maps on the Computer - coordinate systems - data structures and map topology - file formats and conversion for exchange	2 weeks	Chapter 3
Acquisition of Map Data - digital maps - map data in the public domain - data entry, editing, and validation	2 weeks	Chapter 4
Geodatabase and Spatial Analysis - query interface - search by attributes - search by geography - statistical analysis - spatial analysis	3 weeks	Chapters 5 & 6
Making maps with GIS - organizing the layout of a map - types of maps and the specific audience - basic principles in map design	2 weeks	Chapter 7
Picking a GIS - GIS and the operating system - GIS functionalities, data and file formats - issues in picking a GIS in practice	2 weeks	Chapter 8
GIS Application case study - pick an application project	3 weeks	Chapter 9

Table 1. Topics covered in **Introduction to GIS**, the undergraduate course

Topic	Duration	Textbook Reference
Introduction to using GIS - basic GIS: map layers - identify, search, label map features - geo-database and attribute information	1 week	O'Looney: Chapters 1,2
Fundamentals of Map Design - coordinate systems and distance - choropleth maps and attribute data - using map overlays	2 weeks	Clarke: Chapter 2 O'Looney: Chapter 4
GIS Processes and Outputs - GIS data models - import of attribute data - map layout and design principles	2 weeks	Clarke: Chapter 7
File Formats and Geodatabases - data structures and file formats - import and export of GIS data - search by attributes and/or geography - analysis of attribute and geospatial data	3 weeks	Clarke: Chapter 3 Zeiler: Chapter 5
Spatial Data Input – Digitizing - creation of map features - creation of new map layers - input from shape files or aerial photos	2 weeks	Clarke: Chapter 4 Madej: Chapter 7
Geocoding and Address Matching - street map and zip polygons - address matching with street layers - address matching with zip codes	2 weeks	Clarke: Chapter 5 Zeiler: Chapter 11
Spatial Data Processing and Spatial Analysis - problem solving using map features - data query to extract map features - proximity analysis and planning	3 weeks	Clarke: Chapter 6 Mitchell: Chapters 5,6

Table 2 Topics covered in **GIS: Tutorial and Applications**, the graduate course.

Organization	Web Site
National Center for Geographic Information & Analysis	http://www.ncgia.ucsb.edu/
University Consortium for Geographic Info Science	http://www.ucgis.org/
US Census Bureau	http://www.census.gov/geo/www/
US Geological Survey	http://www.usgs.gov/

Table 3. Source for public map data on the web.