COMPUTING FOR GIS

Written by Ross Miller
British Columbia Institute of Technology

Context

The diffusion of GIS technology into society has occurred rapidly in recent years. Today GIS is visible in our everyday lives - from travel maps on the World Wide Web to countertop workstations in City Halls. The reasons for this are many - more readily available data, better dissemination of data through telecommunications, easy to use point and click interfaces and readily available data format translators are but a few. These advances suggest that GIS is becoming less technical in nature, which is partially true for many end users. But, there nevertheless remains a need in the industry for graduates of college and university programs to be well grounded in various aspects of computer technology. An excellent article in the Spring 98 ARCNews by Duane Marble argues that this is necessary if GI science and technology to continue to advance.

Overview of this Unit

This unit is designed to assist the technical GIS educator in identifying the computer skills required for GIS tasks. Basic computer literacy skills are presented as a foundation for technical GIS computing skills. The latter are organized into several categories (e.g. 'Systems', 'Programming', 'Databases'), with lists of skills at different levels of achievement (Awareness, Competency, Mastery). The computing skills are hyperlinked to the Follow-up Units section.

The Example Applications sections presents 3 common implementation models of GIS programs or courses in Community Colleges, based on the amount of GIS and computer courses included in the curriculum.

Basic Computer Literacy Skills

An assumption of this unit is that the student possesses the following basic computer literacy skills prior to entering a GIS course or program;

- Keyboarding skills

- Basic operation of a standalone PC
- Identification, understanding and use of common external hardware components (floppy drives, CD-ROM drives, printers etc.)
- Use of application software such as word processors, text editors, and spreadsheets.
- Navigation of hierarchical directory structures
- Basic Management of files and directories (copy, move, delete, rename etc.)
- Internet navigation skills

GIS Computing Skills

Technical GIS computing skills can be organized into several categories;

- **Programming** This category covers a wide range of programming skills, from menu and toolbar customization to component software programming for GIS.
- **File Handling and Databases** Covers file types, database models, architecture of GIS and databases.
- **Application Software** Focuses primarily on the use of GIS and CAD software.
- **Computer Systems and Networking**Covers a wide range of topics, from basic knowledge of computers systems concepts (e.g. numbering systems) to system administration tasks.

Example Application

The implementation of GIS courses and programs in community colleges can be roughly categorized into three groups;

Group 1 - Community Colleges which have 1 or 2 courses in GIS within a traditional course of geographic studies. The focus is on providing the student with exposure to basic principles of GIS, applications examples and elementary use of GIS software. There may be little or no flexibility in the curriculum for the student to take additional computer courses. Generally speaking, the student will possess good awareness and some competencies in the various categories of GIS computer skills after completing the course of studies.

Group 2 - Community Colleges with an AAS or similar degree or certificate program in GIS, which have a component of computer skills required for graduation. For example, there may be a required programming course for GIS customization, or a course in Relational Databases or CAD. Students gain some computer competencies and mastery.

Group 3 - Institutions which offers a highly specialized diploma/certificate program in GIS, and which are characterized by significantly more emphasis on programming, systems, databases etc. Such programs might require a university or college degree as prerequisite, and the course of studies centers on GIS and related subjects. Students gain competency and mastery in many areas of computing.

Learning Outcomes

The following list describes the expected skills which students should master for each level of training, i.e. Awareness/Competency/Mastery.

Awareness is demonstrated by being able to define each concept, for example, 'What is a computer program ?'

Competency is demonstrated by being able to to apply knowledge in a practical fashion. For example, students would be able to write computer programs in a high level langauge.

Mastery is demonstrated by being able to apply knowledge in a practical fashion, in an area of advanced computing technology. For example, students would be able to develop a GIS application using component software technology.

Programming

Awareness:

Learning Outcomes

The student should be able to

- describe what programming languages are
- give examples of modern computer languages
- describe basic processes of programs e.g. input, output
- outline the program development cycle
- describe 'generations' of languages
- distinguish between interpreted and compiled programs
- describe basic data types used in programs
- understand the role of programming in GIS technical work

Vocabulary

- computer program
- low level language
- high level language
- interpreter
- compiler
- design time
- syntax
- run-time
- algorithm
- source code
- object code
- executable code
- procedural languages
- declarative languages

Competency:

Learning Outcomes

The student should be able to

- customize GIS software interfaces (e.g. menus, tool bars) using built-in tools
- write programs using scripting languages (e.g. AWK, PERL) and apply these to data handling tasks
- customize GIS software using proprietary langauges such as MAPBASIC, AML, Avenue
- write programs using a high level language such as Visual Basic, using
    - data types and declarations
    - language elements
    - decision making
    - flow of control
    - file input and output
    - sub-programs and functions
    - data structures
    - user-defined data types
    - setting properties and methods for objects
- develop well structured and documented computer programs
- use flowcharts and/or pseudocode for program development
- test and debug programs
- implement well designed forms for a user interface
- define event driven and object oriented programming
- design and implement algorithms for geo-data handling and problem solving

Vocabulary

- variable
- constant
- operators
- precedence
- character
- string
- real
- float
- Boolean logic
- truth tables
- structured programming
- subroutines
- functions
- flowchart
- pseudcode
- event driven programming
- object oriented programming
- properties
- methods

- classes
- inheritance
- encapsulation
- polymorphism

Mastery:

Learning Outcomes

The student should be able to

- code advanced data structures such as linked lists, trees
- develop applications which integrate/link 2 or more application softwares/languages (e.g. AML calls to C language programs)
- develop GIS applications using component software programming (e.g. MapObjects, MapX)
- develop object oriented programs using C++, Java, Magik
- develop web pages using HTML, Javascript, VB script
- deliver GIS data to a web browser, using dynamic HTML pages

Vocabulary

- binary trees
- linked lists
- queues
- interprocess communication
- interapplication communication
- dynamic link libraries
- object linking and embedding
- applications programming interface
- dynamic data exchange
- common gateway interface
- Active Server pages
- dynamic HTML
- Active X
- Common Object Model

Files and Databases

Awareness:

Learning Outcomes

The student should be able to

- differentiate between program and data files
- describe the organization of data files (records and fields)
- distinguish between fixed and variable length records

- describe common methods of data file access
- distinguish between binary and text (ASCII) files
- describe the file processing environment
- define a database
- describe common database models
- compare a file processing environment with a database environment for GIS

Vocabulary

- records
- fixed length records
- variable length records
- fields
- delimiter
- CDF - comma delimited format
- SDF - space (standard delimited format)
- DBF
- header records
- trailer records
- sequential access
- random access
- ISAM - indexed sequential access method
- index
- database
- DBMS
- data definition language
- data manipulation language
- SQL
- QBE

Competency:

Learning Outcomes

The student should be able to

- design a database for a simple GIS application
- develop a data dictionary for a GIS dataset
- create and modify database tables
- populate and update database values
- import and export data between files and database software
- normalize a database (1st or 2nd normal form)
- query a database using SQL, QBE or other query methods
- group, sort and analyze database records
- generate database reports

Vocabulary

- table structure

- data types
- field size
- normalization
- relational algebra
- distributed databases
- entities
- relation
- relation table
- indexing
- data modelling
- entity relationship modelling
- primary key
- foreign key

Mastery:

Learning Outcomes

The student should be able to

- develop customized reports from databases
- describe extended relational and object oriented databases
- link GIS software to databases
- customize databases using procedural languages
- perform integrated spatial and non-spatial queries on databases
- perform general DB administration
- use and manage libraries or similar spatial data management tools
- use CASE tools for database design

Vocabulary

- SDE
- CASE
- extended relational databases
- binary large objects
- rollback
- referential integrity
- active data objects
- open database connectivity

GIS Application Software

Awareness:

Learning Outcomes

The student should be able to

- list current commercial GIS applications software
- compare the functionality of CAD-based GIS, desktop GIS, and workstation GIS
- describe the role different GIS software play in the industry
- name third-party and extension products for GIS, CAD and desktop software

Vocabulary

- GIS software
- CAD
- (names of industry CAD/GIS software, e.g. Autocad MAP, Microstation Geographics, Intergraph)
- (names of Arcview extension products, MAPINFO third party products, or similar products for other GIS software)
- desktop mapping/GIS
- third party
- extension

Competency:

Learning Outcomes

The student should be able to

- operate GUI and command line GIS/CAD software
- perform feature/attribute linking
- perform basic operation of GIS applications software;
    - display control (zooming, panning, layer/level/coverage theme display, symbology display)
    - file and data management (opening and closing files, managing projects/workspaces)
    - feature addition and editing
    - acquisition and display of images for reference and heads-up digitizing
    - elementary query and analysis (what is ... ?, where is .....?, proximity analysis, point/line/poly/ in polygon analysis
    - produce plot/map layouts for hardcopy production
- describe the many different file types and formats used in GIS

Vocabulary

- menus
- toolbars
- graphical user interface
- command line
- views, windows
- layout
- image file

Mastery:

Learning Outcomes

The student should be able to

- use GIS and CAD software for advanced analyses, such as
    - 3-D analysis and visualization
    - network analysis
    - cartographic modelling
- demonstrate adequate cartographic skills using GIS
- perform advanced data handling tasks, such as
    - conversion from other formats requiring the use of translation tables
    - data input
        - COGO
        - GPS
        - raster > vector scanning and conversion
- develop applications using internet map server technology

Vocabulary

- routing
- allocation
- cartographic modelling
- client side
- server side
- spatial database engine
- libraries

Computer Systems and Networking

Awareness:

Learning Outcomes

The student should be able to

- describe the basic components and functions of all computer systems
- explain the basic functions of operating systems
- name common operating systems used in GIS
- describe different types of computer systems
- describe different types of computer networks
- describe client server architecture
- describe common hardware used in GIS
- describe how numeric and character data is represented in digital form

Vocabulary

- mainframe
- minicomputer
- microcomputer
- electronic data processing
- on-line transaction processing
- decision support system
- centralized system
- distributed system
- peripherals
- storage devices
- random access memory
- read only memory
- bit
- byte
- octal
- hexadecimal
- server
- client
- network
- LAN
- WAN
- intranet
- scanner
- plotter
- digitizer
- workstation

Competency:

Learning Outcomes

The student should be able to

- use operating systems commands for system and file management
- install, configure, test and operate peripherals for GIS workstations, e.g.
    - digitizers
    - printers
    - plotters
    - scanners
    - data loggers
- install, configure and test internal cards (e.g video, network interface cards) and memory into computers
- install and configure operating systems and applications software
- compress and decompress GIS data sets
- transfer GIS data sets across networks and computers using electronic means

Vocabulary

- file system
- slot
- port
- serial communication
- parallel communication
- IDE
- SCSI
- ZIP
- FTP

Mastery:

Learning Outcomes

The student should be able to

- setup and administer user accounts on a computer network
    - set appropriate permissions for data access
    - set proper security
- establish and administer backup procedures for GIS data
- perform hard disk management
- perform spatial data management tasks (e.g. file and directory configuration for libraries)
- describe different protocols used in computer systems

Vocabulary

- applications
- processes
- services
- domain name server
- registry
- incremental backup
- partition
- protocol
- ethernet
- ATM
- TCP/IP

Follow-up Units

The units which utilize some of these computing skills are indicated below.

Basic Computer Literacy Skills

Unit 20 covers the use of text editors.

Unit 21 covers the use of spreadsheets.

Programming

Unit 9 demonstrates why students need to know scripting languages and have an understanding of the internal representation of data and files.

File Handling and Databases

Unit 19 covers planning a tabular database, and Unit 22 covers merging spatial and tabular data.

Unit 30 covers validation of database, and Unit 31 general management of database files.

Unit 32 deals with managing digital libraries of GIS data.

Application Software

Unit 13 on digitizing gives examples of data entry and how data management skills, such as edge matching, are used.

Unit 16 covers planning a scanning project and emphasizes the importance of understanding image characteristics for data acquisition. See also Unit 18 on airphotos.

Unit 23 covers in depth the use of CAD software and its role and relationship to GIS.

Unit 24 covers GPS data acquisition; Unit 25 covers COGO input.

Units 26, 27 and 28 are concerned with feature editing

Units 33 to 46 cover basic GIS analysis. See Unit 42(map algebra), Unit 45 (location/allocation), Unit 46 (address matching), for advanced analysis topics.

Computer Systems and Networking

Unit 1 requires the student to have a good understanding of files, transfer protocols and compression methods. Unit 6 also gives examples of how to use the Internet to acquire data.

Units 49 and 50 cover operation of peripherals.

Resources

See the CCTP Resource section for examples of GIS Community College curriculum and courses.

Created: May 14, 1997. Last updated: December 21, 1998.