

# BEST-GIS

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## **Guidelines for Best Practice in User Interface for GIS**

### **Section 6 “List of key GIS operations”**

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## 6. List of key GIS operations

The development of this list is based on the assumption that better informed users can make better decisions regarding their needs, and can then better describe those needs to GIS vendors and consultants during the selection and implementation phases.

It is often difficult for a person to judge the potential value of a tool which he/she has never used. Because new GIS users often do not possess the experience (and thus the information) necessary to objectively judge their needs, this section provides a sample of the common GIS functions (operations) which the user should keep in mind. Some operations will apply directly to the user's intended application, while others may be unnecessary.

The following list contains the more common GIS operations, along with a short explanation:

- if it is a command, a function (two or more commands) or a process (two or more functions)
- the type of data/circumstance on which it commonly works, and
- how the item is most frequently activated.

Based on the requirements stated with the help of the checklist in section 5, the user should select the operations which he/she finds potentially interesting or useful to the intended GIS application. These would presumably form the basis of a statement of user needs, to be presented to the vendors competing for the GIS contract during a system benchmark test. During such a test, the vendor should demonstrate not only that the function is supported (yes or no) rather than how it is implemented, what resources are required in order to finalise the operation, and how the user interacts with the operation (the user interface perspective).

Note: These operations are not necessarily ordered by importance or sequence of use.

### 6.1 Project set-up

- set parameters
- set minimum spatial resolution of each feature
- set coordinate system, map output scale, etc.

Project set-up is normally comprised of a set of commands used to initialise the GIS software, the new or existing database and the viewing parameters. This initialisation may be project-specific or user-specific just as permissions may be granted at a group or user level. Novice users normally enter these commands one at a time, while more experienced users create macro files which may initialise some or all of the necessary parameters.

### 6.2 Data entry

#### Map digitising

Map digitising is the process of passing the location of geometrical features (points and lines) from analogue (paper map) to digital format, creating a vector cartographic database. This is normally accomplished using a mouse-like cursor to follow linework and to register the key points used to represent each feature. Most GIS accommodate this process via a digitising subsystem (often a menu of several commands).

#### Map scanning

Map scanning is the process of digitising geometrical features of a paper map using a black and white or colour scanner, producing a database in raster (cellular, bitmap) format. This is normally a simple process of setting scanner parameters (resolution, colours) and then

passing the map through the scanner/reader. The process is often used as a preliminary bulk data input stage, so that the raster data can be vectored using semiautomatic line-following software.

### **Bulk/batch loading**

Bulk or batch loading is the function whereby a large quantity of data are read from an external source, as in the case of a file of x,y,z coordinates in ASCII format. This function may be a single command taking several parameters indicating the file format or type.

### **Assignment of basic attributes to each feature (ID of point, line, area, volume)**

Attribute assignment is the tagging of each geometric feature in the digital cartographic dataset, usually accomplished during the digitisation of the feature, using the numeric keys on the digitising cursor to enter unique numbers or codes (IDs) . The process is normally integrated in the data collection module of the GIS.

## **6.3 Data conversion**

### **Raster-to-Vector**

Conversion from raster to vector-format of spatial data (usually derived from scanning, see section 1.2) involves either a single batch process, or a semiautomatic operation of line-following. When the input raster has a low resolution (i.e. satellite imagery), a fully topologically and aesthetically correct conversion is achieved by very few GIS (see table 7A).

### **Vector-to-Raster**

The converse of the above function, vector to raster conversion converts the geometric features of a database to a representation using a raster grid of (normally) regular cells or pixels. The process is most often automated as a batch process on a single vector data file, and the user must specify the resolution and extent (number of rows and columns) of the grid, and some cell encoding preferences.

## **6.4 Data validation**

### **Identification/correction of topological errors**

Identification and correction of topological errors in vector map database features -an important quality control process- is a cyclical process involving several commands or functions. Errors (overshoots, undershoots, open polygons) can be visualised and categorised, and then may be edited in a batch process or (normally) manually (see table 7B).

### **Identification and correction of tabular data format**

Often tabular (attribute) databases already exist in relational database management systems (RDBMS), and they are to be "connected" to the geometric part of the GIS; however the data are often not in the desired format or structure. Tables may need to be joined or split, and new relations between tables formed, according to the desired geographic model. These actions would be executed using several commands within the database management system.

## **6.5 Data visualisation/rendering**

### **Zoom/Pan/change view**

Zooming is the process of magnifying or reducing the scale of a map or image displayed on the monitor. Panning is the process of changing the position at which the view is displayed, without modifying the scale (see table 7C).

### **Redraw/refresh entire display**

The process of editing and erasing graphic elements on the monitor can often lead to undesirable residual "ghost" graphics which contaminate the view; thus the user would ordinarily refresh the screen with some frequency, using a single command or icon. This function also accompanies the above function, as an automatic process, because the screen image must be redrawn after scales changes or displacements using zoom and pan.

### **Feature symbolisation (simple colour or symbol changes)**

The process of associating certain geographic or label features with selected patterns, colours etc. (i.e. roads may be coloured according to their class or traffic density). This process is normally executed from a symbol editing menu and may also require the definition/editing of reference (look-up) tables.

### **Feature filtering (hide a layer or feature, show another)**

Feature filtering involves the selection of the graphic elements that the user wishes to visualise at a certain moment. Some GIS offer a menu of possible and active features, while others require the user to remember layer or feature names as part of the command sequence.

### **Management of background images**

The process of displaying and managing on the same view vector objects (points, lines, areas) in the foreground and georeferenced raster imagery in the background (see table 7D).

## **6.6 Map database management**

### **Georeferencing (raster and vector data)**

Georeferencing is the process of associating known locations in the real world to the corresponding locations on the cartographic dataset. A subset of these locations, normally of high accuracy, may serve as "control points" to assist in the interpolation of other points in the dataset.

### **Joining of map sheets/tiles (edgematching, etc.)**

Many GIS packages allow the segmentation of large spatial databases into tiles or pages, for reasons of optimal memory management or user convenience during editing. These tiles can become cumbersome artefacts during analysis and, thus, the GIS normally allows for the stitching or joining of tiles as well as the general concatenation of map data files (e.g. to join a new urbanisation to a city map). The process is often a manual one, requiring considerable user intervention to precisely guide the joining of features at tile boundaries.

### **Rectification/conflation of layers (i.e. satellite image with vector map)**

It is a common occurrence that various data layers (e.g. soils, roads, land-use) of the GIS database come from disparate sources, scales, coordinate systems, etc., making rectification of one layer with another base layer a necessary operation. This operation often requires

substantial user intervention, as control points must be selected and/or introduced and then several slight modifications may be necessary, especially when one layer is to be aligned (conflated) to precisely match another.

### **Projection change**

Various input maps might have different projections, a mathematical treatment of the coordinates to adjust for Earth curvature while preserving angles, areas, or distance. These projections may be changed to suit a particular project or to be consistent with other data layers, and normally involves a single or few batch commands on the cartographic file in question.

## **6.7 Attribute database management**

(assuming relational database manager)

### **Link (join) basic attribute to main database**

Often during the digitisation process a single unique ID number is associated with each feature (e.g. each line segment of a road network), the feature's initial attribute. That attribute then must be connected (joined) to the main attribute database to provide graphic query capability of the type "what are the characteristics of this <select with mouse> object? This linking process is normally a function of the database management system chosen

### **Establish more complex relations**

Relational database management systems (RDBMS) are normally used within GIS packages, because of their ability to define complex relations between key feature attributes; this allows for quite complex models to be constructed (see table 7E).

### **Establish connections (SQL, middleware) to secondary databases/systems**

GIS is often introduced to an organisation which already has an information system in place and where existing (legacy) systems hold data which is valuable to GIS applications. It is often a nontrivial task to connect the GIS to the wider system, using middleware applications to translate from one to another; normally an expert creates the application and then the end user executes a command or set of commands to connect to and utilise the external system.

## **6.8 Data processing/analysis**

### **Create/save database views (via RESELECT)**

"Databases views" is technical terminology for the issue of queries to the GIS of the type "show me the segments of the selected highway which have not been maintained in the last 36 months". These segments could then be saved as a selected set, called something like "priority segments", for later processing. This process is normally based on the inherent capabilities of the relational database manager (see table 7F).

### **Proximity analysis (buffer, distance calculation)**

A common spatial analytic procedure is the calculation of features within a certain distance (often radius) of another feature set (see table 7G), as in "show the parcels within 100 metres of the selected highway". This process can be a direct query which results in the selected elements (or grid-cells) being highlighted in another colour, or it may involve several commands to first define the proximity polygon and then to query its intersection with other features.

### **Spatial joins (overlay)**

Still considered the GIS' fundamental analytical operation, overlay involves calculating the

spatial coincidence or intersection of the features of two or more layers, producing a resultant layer and the associated joined attribute tables (see table 7H).

### **Network analysis (optimal routes, allocation of resources)**

GIS which utilise topological vector data structures to preserve connectivity often include the ability to calculate shortest distance and other network trace analyses. These are useful for transportation applications such as distribution, routing, navigation, etc. as well as the management of resources over the network, such as gas, electricity and telephony. The process is quite complex; first the user must create the network model, then set the proper attributes (speed limits, turn restrictions, flow impedance, etc., and then must run the analysis routines and display the results.

### **Raster analyses (map algebra)**

Many GIS allow the processing of raster data, taken normally from remotely sensed imagery. Among the available raster analysis is normally the ability to overlay raster maps for processing using "map algebra". Often the GIS will have a separate subsystem devoted to this processing, which uses its own language and methods.

### **Generalisation/smoothing/dissolve**

Among the most widely used cartographic functions are those designed to simplify and generalise vector cartography, reducing the points necessary to represent features, merging similar neighbouring areas, etc. This is usually implemented as a set of singular commands, and a word of caution is in order regarding their appropriate use.

### **Digital terrain modelling (incl. simple creation of 3-D views)**

This is the complex process of building a three-dimensional representation of a surface, given a set of elevation points (z values). The representation normally serves only for improved visualisation of an area of interest. The GIS often includes a subsystem for importing, manipulating and viewing these models (see table 7.I)

### **Secondary analyses (on DTMs)**

- drainage, flow
- slope/aspect
- other...

Once the Digital Terrain Model (DTM) is created and edited, it may become the basis for secondary analyses of terrain-based phenomena such as erosion, slope and aspect determination, line of sight, etc. These analyses are frequently user-defined, and programmed with the system's macro language (see table 7I)

## **6.9 Output: map production /reports**

### **Generate summary statistics**

Among the tabular (non-cartographic) products which may be generated by the GIS, summary statistics (i.e. sum, mean, standard deviation, etc.) of key attributes (e.g. area of polygons) may be calculated. These are often single commands, issued from within the GIS' database manager.

### **Generate text report from attribute database**

The database management system (DBMS) may also allow the generation of summary

text reports from the attribute tables. This is an important output, given that often the GIS analyses graphic features, but then reports tabular results. These are also generated from within the DBMS, and thus will vary from system to system.

### **Generate simple map**

Most commonly a GIS produces cartographic output in the form of a simple map. The system may ask for several graphic parameters to be specified, and then the drawing appears with a single icon or command.

### **Generate complex graphic product (map composition)**

The combination of map layers, tables, legends, etc. in order to produce a complex graphic output (i.e. a poster) which includes information from many sources. This process is often executed from within an output subsystem, and involves composition and design, complex symbolisation from attribute tables, and knowledge of plotting parameters such as scale, print size, etc. (See table 7J).

### **References**

*See section 7*