Chapter 4

Functional Units of a GIS Workstation

As has been pointed out in Chapter 1, GIS technology finds application in a wide spectrum of problems, in research, in small or self-contained projects, and as an integral part of corporate activity and planning. Potential applications for GIS range from single, well-focussed ones like route planning, to computer-supported collaborative work systems wherein, groups of users, separated geographically, simultaneously develop a single cognitive map based on a problem/solution [Mennecke 1997].

Because the range and scope of the applications vary widely, configuring GIS workstations should take into account not only the wide range of uses, but also the wider range of users. The capabilities of GIS users vary from technically competent professionals interested in tackling complex problems, to individuals of below-average ability whose job is confined to repetitive, uninteresting tasks. For systems intended for tightly focussed applications in a stand-alone environment, an essentially static, uncusomisable user interface would suffice. The ‘spatially aware professional’, on the other hand, would rather work in a sophisticated GIS environment with complex visualisation user interfaces equipped with a large number of available commands [Raper & Bundock 1993]. It will therefore be prudent to examine the most comprehensive GIS which could set the standard for other systems.
4. 1. THE SEQUOIA 2000 PROJECT

THE requirements of a modern, state-of-the-art computing environment for global change researchers, scientists involved in studying ozone depletion, environment toxification, species extinction, simulating and forecasting world climate ten or even hundred years ahead, were formulated in June 1990, and a long-term project got underway in 1991. The focus of research under the Sequoia 2000 project was a high speed, broadband network spanning University of California (UC) campuses from Berkeley to Santa Barbara, Los Angeles, and San Diego, a massive database, massive storage, visualisation system, and electronic collaboration.

The participants in the Sequoia 2000 project included

Computer Science Division, UC Berkeley;
Computer Science Department, UC San Diego;
San Diego Supercomputer Center;
Department of Geography, UC Santa Barbara;
Atmospheric Science Department, UC Los Angeles;
Climate Research Division, Scripps Institution of Oceanography;
Department of Earth, Air, and Water, UC Davis;
Department of Water Resources, State of California;
Department of Forestry, State of California;
Coordinated Environment Research Laboratory, US Army;
NASA, USA;
National Oceanic & Atmospheric Administration, USA;
US Geological Survey;
Digital Equipment Corporation, Hewlett-Packard, Hughes Communications, MCI, Siemens, and TRW

The objectives of the project and the nature of its participants have made Sequoia 2000 the converging point of a great deal of technological resources. The status of the project as of 1995 has been described in [Stonebraker 1995], [Larson et al. 1995], [Kochevar & Wanger 1995], and [Pasquale et al. 1995].
4.1.1. Specifications for Sequoia 2000

The set of product requirements that were validated through discussions with the potential users included

- A computing environment built on a data-centric system.
- A database that handles a wide variety of non-traditional objects such as text, audio, video, graphics, and images.
- Support for a variety of traditional databases and file systems.
- The ability to perform necessary operations from computing environments that are intuitive and have the same look and feel. The interface to the environment should be generic, very high level, and easily tailored to the user application.
- High-speed data migration between secondary and tertiary storage with the ability to handle very large data transfers.
- Network bandwidth capable of handling image transmission across networks in an acceptable time frame and error tolerance.
- High quality remote visualisation of any relevant data regardless of format; the user must be able to manipulate the visual data interactively.
- Reliable, guaranteed, delivery of data from tertiary storage to the desktop.

Used as a GIS, Sequoia 2000 has extensive capabilities for manipulating and displaying spatial information. It supports spatial data such as points, lines, and polygons. In addition, the DBMS supports the large spatial arrays in which satellite imagery is stored in its natural form. These characteristics are beyond the realm of popular, general-purpose relational and object-oriented DBMSs. The nearest setup that met the above requirement was either a special-purpose GIS or a next-generation OODBMS. Since POSTGRES (vide Pages 63, 68, & 76) was an object-relational system, the Sequoia 2000 project chose it as the database. It has since been extended to support basic spatial data processing tools that are adaptable to standard spatial models. Unlike many commercially available GIS software wherein, spatial data handling functionalities are provided as separate sets of executables operating on
private data structures, Sequoia 2000 provides these functionalities as an integral part of the DBMS design.

Providing this level of functionality in the DBMS requires implementing geoprocessing primitives as POSTGRES operators and providing visualisation tools for examining the outputs. To address this, a set of representative queries has been developed. The queries are organised according to four basic spatial data types \( \text{viz.} \):

- **raster**: multiple image selection by region, spectral analysis, resampling.
- **network**: graph traversal.
- **polygon**: clip to region, boolean selection by attribute.
- **point**: selection by region.
- **joins**: raster + polygon, raster + point, polygon + point

Presently POSTGRES supports coordinate data in both vector (polygon and line) and point formats. Raster data are represented as large objects, which are interpreted and processed, based on identifiers specifying number of dimensions, size, and organisation of arrays (row or tile), and pixel or cell format. Figure 4.1 provides an overview of the Sequoia 2000 geodata framework, highlighting the relationships among feature-based views and map coverage perspectives [Gardels 1994].

In spite of the enrichment of POSTGRES through augmented functionalities, it is bridled with the legacies of a typical relational database, particularly with respect to the lack of isomorphism that information on entities are subjected to, when they are dissipated over several tables during the process of normalisation. And the effect of this is most awkward in the case of geographic data.
Figure 4.1. The Geodata Frame Work Adopted for the Sequoia 2000 Project

Adapted from [Gardels 1994]
4.2. SCOPE OF THE PRESENT WORK

As indicated in Section 4.1, Sequoia 2000 is a project unmatched in its immensity of collaborative expertise and the sweep of technological features that are part of the project specification. The Sequoia project is relevant to the present work, insofar as it defines the state-of-the-art in GIS. For obvious reasons, the framework adopted for KBGIS, could only be a small subset of that for the Sequoia 2000. It corresponds to the left-most branch of Figure 4.1 and, as shown in Figure 4.2, it focuses on spatial and geometric objects, viz., points, lines, curves, and polygons—objects that occur most frequently in common GIS applications such as route planning, urban/rural planning & development, resource allocations concerning schools, hospitals, police stations, et cetera, site selection of industries, schools, electrical transmission lines, and many others. The subset chosen can provide distribution of existing objects, and distance analysis. Since roads are treated as chains, with junctions acting as nodes connecting the short links, the shortest route from one location to another can be determined and reported by the system. It can
generate thematic maps using overlays. A schematic of the functional units of such a system is shown as Figure 4.3.

![Figure 4.3. Functional Units of a Knowledge-Based GIS](image)

4.2.1. Specifications of the Proposed GIS

The requirements that are to be met by KBGIS are as follows:

1. The system will be designed as an experiment to study the feasibility of using a knowledge base in place of a relational database that has been the tradition for most GIS designs.

2. The source of input spatial data is mostly sheet map that are to be manually digitised.

3. It should have suitable data handling facilities for converting the digitised data into formats suitable for storing as working memory elements (WMEs) in a production system.

4. Points, lines, curves, and polygons, are to be handled appropriately, along with their relevant attributes.

5. An editing subsystem should be capable of editing the entries made as WME. The editing subsystem should also have the capability of inputing new digitised data into the working memory. It should also facilitate entering and editing the productions in the rule base.

6. The query subsystem should hold a number of standard parametric query statements, any one of which can then be
invoked by the user, either in the original form, or modified through changing the parameters.

7. The **functions** subsystem should have routines for customising and manipulating the screen layout, window layout, form layout, and for interacting with the GUI, so as to effect various display manipulations (zoom, pan, window sizing, scrolling, *et cetera*). The functions subsystem should also act as an interface between the query and the display subsystems.

8. A **library** subsystem should act as a repository for the various routines, queries, files containing the coordinate pairs of linear objects like roads, rivers, *et cetera*. When the query process finds as the result of a search a road and its corresponding road-number, it could fetch the file of that road and have the coordinates and other relevant attributes of the road displayed on the screen.

The methodology adopted for realising the requirements defined by the above specifications are covered in the next chapter.

### 4.3. SUMMARY

THIS CHAPTER has examined the features of a technologically sophisticated GIS, developed as part of the Sequoia 2000 project. The GIS is based on **POSTGRES**. POSTGRES functions essentially as a relational database system; but the relational model has been modified in the areas of data structure and object management. One goal of the project was the development of a multiterabyte storage system that would be available to the users over high-speed network.

A small subset of that system is chosen as the defining scope of the present work. The requirements of the proposed system have been specified. It is built around a production system, with separate knowledge base and rule base.