Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

Dynamic linking between GIS and surface water databases

J. Zhang & Y. Parks

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxfordshire, OX10 8BB, UK

Abstract

Within the field of surface water hydrology the use of relational databases is being extended to include Graphical Information Systems (GIS). The method proposed in this paper involves using two separate databases to manage the GIS and the surface water database, and provides dynamic links between the two components. These components perform distinctive tasks - the GIS is responsible for manipulation of visual objects as part of the user interface; the surface water database performs data retrieval and processing in response to the requests from the GIS. Since links between the GIS and the surface water database are dynamic, the two separate components can be set-up independently providing flexibility.

1 Introduction

A surface water hydrological database and analysis package (HYDATA) has been developed by the Institute of Hydrology, UK. The package has been sold to over 20 countries since its first release in 1987. The challenge currently facing the HYDATA development team is to provide a GIS user interface in the Microsoft Windows environment. In current GIS applications, the existing data have to be converted to conform to the GIS data structure. Almost every GIS application has also to develop a unique map user interface. If HYDATA takes the same approach, the existing database structure has to be changed, this will result in the new release being incompatible with previous releases. Secondly, if the GIS map interface is specifically integrated to with HYDATA database, the map interface cannot

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

be used for other software development. To solve these problems, research has been conducted, and a new method has been found which will provide GIS access to existing databases, thereby encouraging reuse of code for other applications. This paper presents the method of coupling GIS into current database systems through dynamic information links.

2 Current GIS review

A geographical information system (GIS) is regarded as a system of a map interface integrated with a data management system. The GIS is a special case of an information system, with the map interface objects providing easy access to the database information. Currently GIS demand is outstripping supply, and the explosive growth in the take-up of GIS has relied on a relational database allied to mapping facilities, and geometric processors.

Dickens[1] summarised three key components and Cowen[2] summarised four basic approaches in developing GIS applications. The three key components are GIS technology, a GIS database and GIS infrastructure. The four basic appoaches are the process-oriented, application, toolbox and database approaches. The process-oriented approach emphasizes the information handling capabilities of GIS by DoE[3]. The application approach divides information systems on the basis of the problems they seek to address. The toolbox approach emphasizes the generic aspects of GIS as represented by the widely used definition of Burrough[4]. The database approach is typified by integrating GIS and relational database systems to make the database conform to the GIS structure; e.g. Maguire[5] and Dueker[6].

The researches in GIS currently pursued are typically defined by the NCGIA (USA) and RRL (UK) and are:

1. Accuracy of spatial databases
2. Spatial decision support systems
3. Visualization of the quality of spatial information
4. Temporal relations in GIS
5. Space-time statistical models in GIS
6. Remote sensing and GIS

With the amount of work being carried out in the field of GIS, there is now arguably a subfield within physical geography and environmental science which can be characterized as "Environmental GIS". This subfield carries out research of particular interest to environmental modelling, monitoring and impact assessment through spatial analysis. Much of the work has involved, linking models and analysis with GIS using digital

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

elevation models; e.g. Walsh & Butler[7]. This approach provides a specific solution but is not a suitable direction for a generic GIS approach because the analyses and models linked to the geographical data do not exploit the relationship between the geographical data and other types of data. Therefore the method of linking models to a GIS and database has to be further examined.

3 Geographical Dynamic Information System (GDIS)

Geographical dynamic information systems (GDIS) separate the map interface and database management tasks, and provide a methodology to link the map interface with the database. The GDIS is like a sandwich where the top layer is the map interface, the bottom layer is the database management system, and the dynamic links are in the middle. The purpose of the GDIS model is to achieve the maximum efficiency both by reducing the duplication of work in developing many specific map interfaces, and by reducing the need for conversion of existing data to conform to a GIS data structure. In the sandwich model, the map interface requires no knowledge of the database management system, and the data within the database does not have to conform to a specific GIS structure.

3.1 GDIS component: Map interface

The purpose of the map interface is to acknowledge the selection of any map object by updating the user interface and the pool of selected objects. The middle layer of the GDIS contains dynamic links; the links serve two purposes, one is to provide access links between the map interface and the database management to enable quick access and updating of both the database information and the attributes of map objects, another purpose is to browse the database or the map interface objects information before processing and displaying the information.

In the GDIS system, the map has associated with it minimum information to handle the visual objects and their attributes. The map components include areas, lines and points. The GDIS background must be linked to default background processing functions to meet the demand of raster data display. The visual objects in the map components can be divided into active objects and grey objects. An active object is an object linked to the database either by access links or process links, and a grey object is not linked. When selected, an active object will be added to a pool of selected objects and the user may query or update information regarding or linked, through access link, to the object. At the same time, the display of the object will be highlighted. When selected, a grey object does not give any visual feedback, since there is no access or process link associated with the object. In this case, the background processing link will be used to provide default information for the grid square associated with the grey object.

3.2 GDIS component: Links

The links between a map object and the database tables can be shown in Figure 1.

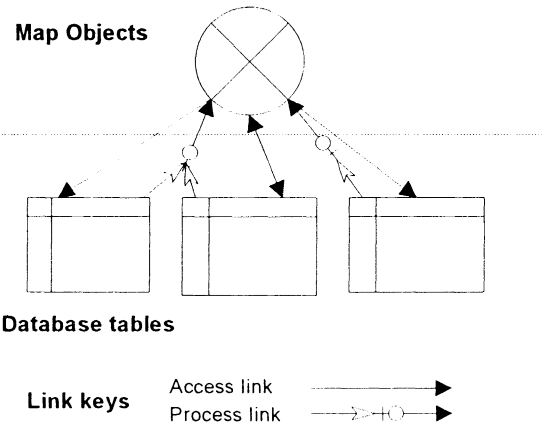

Figure 1: Dynamic links between database and GIS object

Under the GDIS, the database information is no longer simply projected onto the map but is linked to the map objects through either access or process links. This provide an increased flexibility whereby a single item of information in the database can be linked to multiple map objects. Also multiple items of information can also be linked to a single map object. For example, in a satellite GDIS system, a two table relational database could have one table for satellite location and transmision information, another table for satellite channels and programs. An example of a multiple database link to a single map object could be the two tables linked to one satellite control center, through access links, to enable the updating of both satellite and program information. As an example of single database information linked to multiple map objects consider a program table being linked to several centres, through access links, for updating different channel programs. Using a background processing function, the information about the satellite coverage and programs can be determined for any location in the map based on satellite locations and the location in the map. This system is difficult to implement through the triditional GIS approach since there are no direct links between the database information and the map interface. To expand the system, further processing functions may be added to link satellites with map objects to provide the signal strength and the alignment of

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

satellite receiver dishes. The examples of satellite links within a GDIS system are shown in Figure 2.

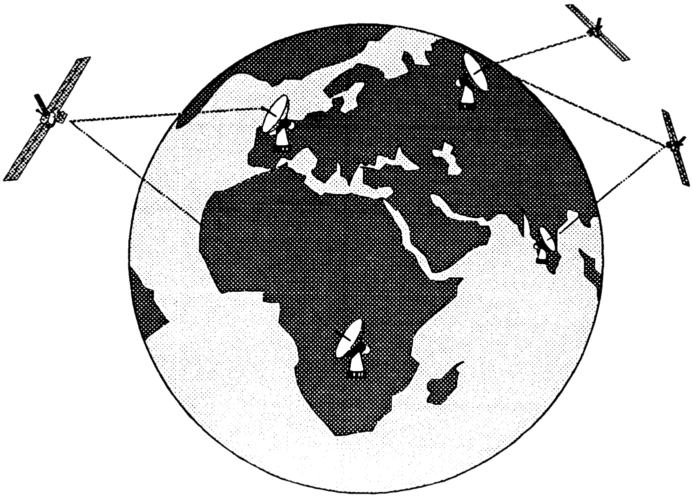

Figure 2: Satellite GDIS

Another example is an air quality GDIS system. In the system, the database contains pollution sources and weather conditions. The map background may be linked by a process link of a pollution dispersion model. The pollution sources and weather database provides inputs for the model to calculate the air quality in any location within the area. The system may help people to make their weekend picnic plans by avoiding the pollution from nearby power and chemical processing plants.

The GDIS system can solve typical GIS problems in the following areas:
1. Data conversion: since there is no need to convert data to conform to the specific GIS data structure, any existing data can be used through dynamic links.
2. The accuracy: without the need to merge map data and other data, accuracy problems will no longer be an important issue, since improvements in process links can be much more easily carried out than matching corresponding data in a data conversion exercise.
3. Spatial statistical processing: Process links can obtain information both from the map interface (location) and database, hence spatial analysis can be added whenever required.

In fact the dynamic links described can provide all the necessary links. The links can access multiple attributes within multiple databases as well as

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

attributes in multiple map objects. With the future support of open database connectivity, database information may physically be stored under different database management systems in different locations. The map interface will be a window to view all possible information using dynamic links.

4 Software implementation of GDIS

4.1. Map interface

For software development purposes, the GDIS sandwich model requires closer inspection. The first component in a GDIS is a map interface, where areas, lines and points make up the map objects in a two dimensional map. Since the attributes of the map objects have to be stored in a database, a local spatial database is required to support the map interface. The map objects in the spatial database are organised into layers to achieve the maximum efficiency for object selection. In the spatial database, objects may be grouped into layers by the object types, and each object has a visibility option in addition to other options such as colour, size etc. A layer also has a visibility option to enable all the objects in that layer to be visible or hidden. In this way each user may view appropriate information choosing and overlaying layers to his specification.

The following provides an example of the use of layers to store map information. By default, the background of a map is the base layer, there are no objects in the base layer. The base layer is an area tiled by tiny rectangles which are not visible unless some database information is mapped onto the base layer, and in this situation the base layer will function as the raster surface. The size of the small rectanglular tiles in the base layer can be changed to suit the discretisation of the data to be viewed. An example of this surface is the base layer merged with elevation data for the region to show the geographical profile of land surface. Next upon the base layer is a group of layers containing area objects, the group contains all visible natural and permanent man-made objects such as lakes and built-up areas. Next to the group of area object layers is a group of layers containing line objects. Again these layers include natural and permanent man-made objects such as rivers, coastlines and roads. The next group of layers contains points and can be used to display point objects such as cities, river guaging stations and bridges etc. On top of the point group, there is a group of text layers. The top most group of layers are abstract objects which include lines and points or combinations of lines and points. The text layers and the abstract layers do not contain active objects as they are only intended to help to identify the map locations. The city and country names reside in text layers, and grid lines in abstract layers. In each layer, there is a pool of selected objects to store the objects which are currently selected. The diagram of map layers is show in figure 3.

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

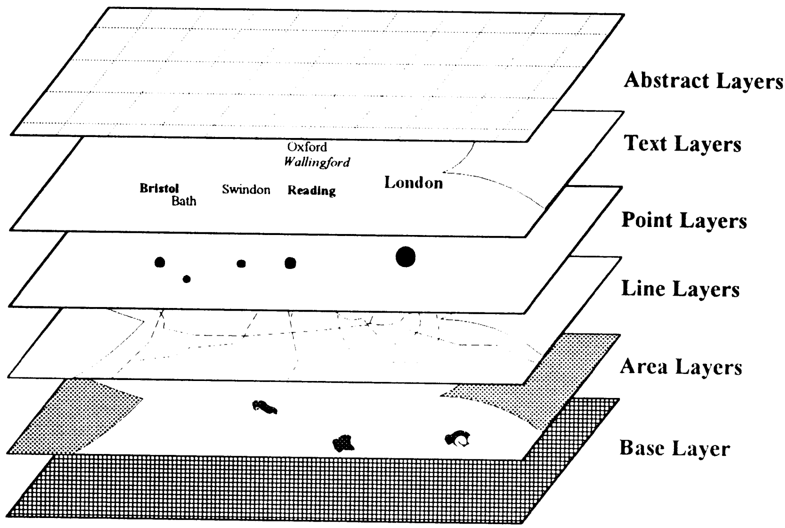

Figure 3: Diagram of GDIS layers

4.2 Dynamic links

The dynamic link components have the functionality to link map objects to the database either by access links or process links. Dynamic links are stored in two index tables corresponding to the access or process links. In the access link table, a typical link includes the identification of a map object and the database table, records and attributes. In the process link table, a link includes the identification of a map object and its processing function. If a map object has its link recorded in the link index table, the object becomes an active object, and will be highlighted when selected. The access link provides access to database information and can be used to update the database information. The process link can only read the database information. As the GIS system is designed to access and display database information, it is vital to make sure all the database is accessible through at least one access link, because this provides the primary database data entry and processing facility. The process links can be used to browse through the database and process the data for display.

4.3 Database management

The database management systems can be any database storage and retrieval system as long as it provides the primary functionality of capturing, storing, editing and retrieving data. The information in the database can include almost anything from social, economic and natural sciences. The database format is not restricted to the record based relational database. It can be any form which includes text files and object-stores.

5 Surface water hydrological database (HYDATA)

The new release version (HYDATA V4.0) of surface water hydrological database and analysis is currently under development. The new version is a Microsoft windows application, the database uses a relational database and is composed of 9 primary tables and 21 secondary tables. The primary tables provide storage for basic surface water hydrology data and the secondary tables support efficient operations, user management and multi-language support. HYDATA also performs hydrologicial data processing and analysis including ratings, flow duration curves and low flow analysis.

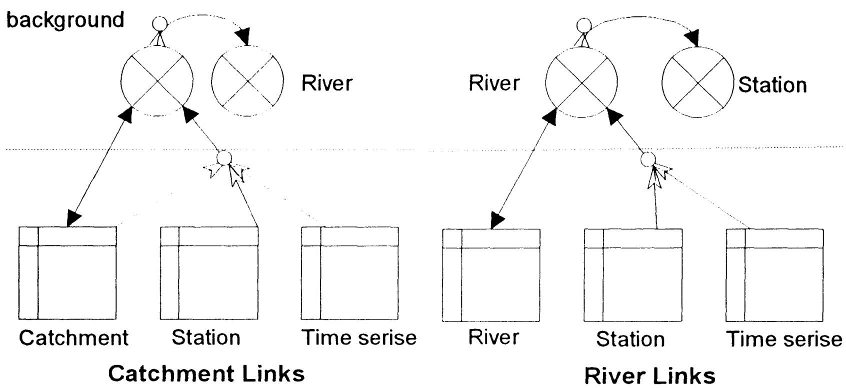

Figure 4: HYDATA GDIS

Since HYDATA stores geographically based data, the system can be easily mapped to a GIS system. The correspondence between the geographical map and the database tables is linked to the background display, and the background is linked to the catchment database table by an access link and to time-series tables by a process link. The access link can be used to update the catchment information, and the process link can be used to estimate the monthly or annual rainfall for the catchment. All the river segments on the map are dynamically linked to the rivers in the database by access links to enable the update of river information. River segments are also dynamically linked to stations by process links to obtain river discharges at specific station. The stations on the map and stations in the database are linked by four access links and seven process links. When a station on the map is selected, the information which can be accessed and edited includes

Transactions on Ecology and the Environment vol 6, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

general station information such as name, altitude, latitude and longitude; Station type information such as river level, lake level, rainfall, lockage etc; Time series data for the station; River gauging data such as stages, velocity, area etc. The process links are used to produce the hydrograph, annual summary of daily data, rating graph, low flow duration curve, low flow frequency analysis, hydrograph recession and double mass plot. The actual linking is performed by using the unique number of the map object and relating this to the unique number in the database or unique number for the process link. The dynamic links of background and river objects are shown in figure 4. The dynamic links are set-up during system setup and can not be changed by the user. In future, if possible, the links will be set-up by the user during the run time and the user may dynamically make processing functions for the process link to meet special needs.

6 Conclusion

The GDIS system is efficient in handling GIS applications in the field of environmental modelling through the HYDATA example. However, this is only a first step toward the development of a fully structured system to handle the information exchange between a map interface and database management systems. Further research in this direction may lead to a new fourth generation language of GIS. Alternatively results may extend command sets of the current GIS tools such as ARC/INFO to perform the task of registering dynamic links with user defined functions, and linking map interface objects through the registered links to databases.

References

1. Dickens, H. & Calkins, H. N. The economic evaluation of implementing a GIS. Int. Journal of Geographical Information System 2, 307-27, 1988
2. Cowen, D. J. GIS versus CAD versus DBMS: what are the differences? Photogrametric Engineering and Remote Sensing 54, 1551-4, 1988
3. DoE (UK), Handling Geographical Information, Report to Environment Committee, London, 1987
4. Burrough, P. A. Principles of geographical information systems for land resources assessment. Clarendon, Oxford, 1986
5. Maguire, D. J., Goodchild, M. F. & Rhind, D. W., Geographical information system: princles and applications. London, Longman, 1991
6. Duecker, K. J. GIS: towards a georelational structure. Proc. AUTOCARTO7. ASPRS/ACSM, Virginia, 172-75, 1985
7. Walsh, S. J. & Butler D. R. Biophysical impact on the morphological components of avalanche paths. Proc GIS/LIS Atlanta, USA, ASPRS/ACSM, A133-43, 1991