Using a GIS as a DSS Generator

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The continuing development of DSS applications requires that new technologies be exploited to allow new classes of decision be supported. This paper discusses the use of a Geographic Information System (GIS) as a Decision Support System (DSS) generator to create Spatial Decision Support Systems (SDSS). Many important areas of DSS application, such as routing or marketing, make use of spatial information. This paper argues that the development of such systems will allow effective support be provided for decisions which make use of spatial data.

***Keywords** : Decision Support Systems, Geographic Information Systems.*

Introduction

The concept of Decision Support Systems(DSS) is generally regarded as having originated with the work of Gorry and Scott-Morton (1971). While there are many definitions of a DSS, there is general agreement that these systems focus on decisions and on supporting rather than replacing the user's decision making process. There is also a general consensus in the definitions of DSS that both database and model component are usually required to fully support decisions.

In the period since the early 1970s DSS has emerged as an important component of information systems, with an increasing research output by DSS researchers. The growth is reflected in literature surveys of DSS applications research (Eom and Lee 1990). This growth in the importance of DSS has taken place against a background of rapidly changing computer technology. The introduction of widely available personal computers and their one hundred fold increase in performance has facilitated the development of a wide range of DSS applications. Other new technologies such as multimedia or the use of CD-ROM storage open up possibilities for decision support applications which could not have been easily implemented in the early years of DSS.

One area of information systems that has expanded enormously in recent years is that of Geographical Information Systems (GIS). As is the case with DSS there are numerous definitions of GIS; for a review of these see Maguire (1991). The majority of these definitions describe a system for storing and displaying spatially or geographically related data. GIS has its origins in the fragmented use of computer technology in the 1960s for automated cartography and address matching software. The development of comprehensive GIS software required improvements in graphics and database techniques. By the 1980s a number of different forms of commercial GIS software became available, including widely used products such as ARC/INFO™. These systems generally were used on UNIX workstations. At the end of the 1980s, PC based GIS software become available, reflecting the increase in PC performance to levels previously associated with workstations.

By the 1990s many different types of commercial GIS software were on the market and the technology had achieved widespread use in its traditional areas of application, for example in forestry and natural resource applications. The increasing use of GIS was both facilitated by, and responsible for, the increasing volume of digital spatial data becoming available in developed countries.

Geographic Information Systems

A GIS makes use of geographical and attribute data. Attribute data, addresses, populations, etc., is associated with geographical data. Geographical data may be represented as points, lines or polygons. Attribute data can be handled easily using a conventional database management system (DBMS). It is the handling of the geographical data, such as the existence of rivers, roads or contour lines that requires the use of the special techniques that characterise the use of GIS. A GIS, as distinct from a mapping program, will have a database of geographic data, allowing linkages between different types of data and the ability to query this spatial data. For example a GIS database query might allow identification off all roads with a certain distance of a river. Therefore, while traditional database approaches can support queries on the attribute data, GIS is defined by its ability to cater for spatial queries.

The growth of GIS has been driven by the importance of spatially related data. It is estimated that up to 80% of data needed for the activities of business and government is spatially related (Franklin 1992). The growth in GIS use also reflects the decreased cost of the technology. This explosion in the use of computer technology can also be seen in other areas, where a vicious cycle of declining hardware costs leads to larger software sales and therefore reduced software costs. This trend has lead to some mapping software becoming available on a mass market basis, for example the inclusion of mapping facilities in the Lotus 1-2-3 Release 5 spreadsheet. This mass market use of mapping and GIS products creates a large demand for spatial data, increasing amounts of which are becoming available. Decision makers who make use of basic mapping products, such as those provided with Lotus 123, are likely to become aware of the need for more sophisticated software. Recent improvements in mainstream PC technologies facilitate this increase in the use of spatial data. These include inexpensive gigabyte sized hard disks, large high resolution colour monitors, graphics accelerators and CD-ROM storage.

Many areas of DSS application are concerned with geographic data, including one influential early example of a DSS, the GADS system (Grace 1976). A more recent important prototype DSS, Tolomeo (Angehrn and Lüthi, 1990) uses a geographical context for the development of visual interactive techniques. However there has been limited impact by mainstream GIS techniques on DSS research. This situation is beginning to change. Recent DSS textbooks are including GIS as a component of management support systems (Mallach 1994, Turban 1995). While these texts stress the usefulness of geographically related information, they do not provide a complete picture of the relationship of GIS to other management support systems. GIS related research is beginning to make an appearance at conferences associated with DSS. For example a recent paper by Crossland and Wynne (1994) presented empirical evidence of the usefulness of a spatial approach to decision making. This paper was presented at the Hawaii International Conference on System Sciences, a conference associated with DSS rather than GIS based applications.

GIS techniques are beginning to have an impact on DSS applications. The survey by Eom, Lee and Kim (1993) identified marketing and routing as important areas of DSS application, both of these fields are recognised as areas of GIS application (Maguire 1991). In the area of routing Bodin, who was identified by Eom, Lee and Kim (1993) as an important author in routing DSS, has argued for incorporation of GIS in routing (Bodin and Levy 1994). Keenan (1995) proposed a classification of routing problems with respect to their spatial content and the usefulness of a SDSS. A number of GIS products are aimed at marketing applications, for example the Tactician GIS.

Within the field of GIS there are many who consider GIS software to provide decision support. Indeed as Maguire (1991) points out, some authors have argued that a GIS is a DSS. A substantial number of GIS based applications are described as being DSS. A recent GIS conference was entitled “DSS 2000”. This view of GIS as a DSS is not entirely without support in the existing definitions of DSS. Alter (1980) proposed an influential framework for DSS which includes data driven DSSs that do not have a substantial model component. Standard GIS software could be regarded as an *analysis information system* in Alter's framework, the critical component of such a system being the database component.

However, in many cases, the description of these GIS applications as being DSS is not based on reference to the DSS literature. This may be a reflection of the trend identified by Keen (1986) for the use of any computer system, by people who make decisions, to be defined as DSS. Even where GIS contains the information relevant to a decision, they are usually general purpose systems, not focused on a particular decision. There are many problem areas where GIS techniques can make an important contribution but where models are needed to fully support the decision. For these areas at least, a GIS cannot be said to be a DSS as such a system lacks the support that the use of models can provide.

Spatial Decision Making

SDSS can therefore be seen as an important subset of DSS, whose potential for rapid growth has been facilitated by technical developments. The availability of appropriate inexpensive technology for manipulating spatial data enables SDSS applications be created. The benefits of using GIS based systems for decision making are increasingly recognised. Muller (1993) identified SDSSs as a growth area in the application of GIS technology. However the value of SDSS is not determined by its innovative use of technology. Instead the contribution of these applications will be determined by the need for a spatial component in decision making.

I suggest that three categories of decision maker may find that SDSS can make a contribution to their decisions. The first group is in the traditional areas of application of GIS, in disciplines such as geology, forestry, and land planning. In these fields GIS was initially used as a means of speeding up the processing of spatial data, for the completion of activities which contribute directly to productivity. In this context the automated production of maps, in these disciplines, has a role similar to that of data processing in business. In these subject areas there will be growth of decision making applications in much the same way as data processing applications evolved into DSS in traditional business applications. The greater complexity of spatial information processing and its greater demands on information technology have lead to the ten to fifteen year time lag identified by Densham (1991).

The second group of decision makers for whom SDSS can make an important contribution is in fields such as routing or location analysis. Although the spatial component of such decisions is clear, DSS design has in the past been driven predominantly by the management science models used. In the future these models will be incorporated into GIS based SDSS, providing superior interface and database components to work with the models. This synthesis of management science and GIS techniques will provide more effective decision making, as Keenan(1995) has argued in the context of vehicle routing.

The third group of decision makers who will find SDSS important include those where the importance of spatial data is somewhat neglected at present. In disciplines such as marketing. additional possibilities for analysis are provided by the availability of increasing amounts of spatially correlated information, for example demographic data. Furthermore the availability of geographically convenient product supply locations relative to customers is an important tool of market driven competition. In these areas the availability of user friendly SDSS to manipulate this data will lead to additional decision possibilities being examined which are difficult to evaluate without the use of such technology (Grimshaw 1994).

Building a DSS using a GIS as a generator

Because of the variety of decision making situations where spatial information is of importance, it is clear that SDSS will be an increasingly important subset of DSS in the future. It is useful to examine the relationship of GIS software to such systems. Densham (1991) discusses the development of DSS in the context of the framework proposed by Sprague (1980). In Sprague's framework a DSS may be built from tools, individual software components that can be combined to form a DSS. At a higher level in Sprague's framework are DSS generators, from which a specific DSS can be quickly built. Sprague envisioned that different specific DSS applications would require different combinations of the generator and tools. Sprague used GADS (Grace 1976), which can be regarded as a form of GIS, as an example of a DSS generator.

In building DSS, specific generators have been designed for certain classes of problem. In other situations general purpose software such as spreadsheets or DBMS packages have been regarded as generators. In modern DBMS and spreadsheet software, the use of macro and programming languages facilitates the creation of specific applications. Various generators have strengths and weaknesses in terms of their provision of the key components of a DSS; an interface, a database, and models. In the case of a spreadsheet, modelling is the basic function of the software; various interface features such as graphs are provided, but database organisation is simplistic. DBMS software, such as Access or Paradox, has good database support, provision for interface design through the use of forms, report and charts, but almost no modelling support. In this case the modelling support has to be added to the specific DSS built from such a system.

The decision regarding the appropriate mix of DSS tools and the use of a generator is an important component of the process of building a DSS. However there is a very real sense in which the types of DSS design considered for a given class of problem are a function of the available DSS generators for that class of problem. In practice a small DSS project could be built, using an off-the-shelf spreadsheet or DBMS package, in less time than it would take to fully evaluate the full range of alternative methods of constructing the DSS. Therefore the DSS solutions actually constructed are strongly influenced by the perceived availability of suitable generators. Therefore the effective application of DSS technology can benefit from additional generator software becoming available. Awareness of the potential of the use of GIS based systems as DSS generators will lead to problems, currently being approached in other ways, being approached by using a SDSS.

There is evidence that GIS software is becoming increasingly suitable for use as a generator for a SDSS. As GIS designers gain a greater awareness of decision making possibilities, their systems will be designed to facilitate interaction with models. GIS software provides a sophisticated interface for spatial information. Even limited functionality GIS software will provide the ability to zoom and to display or highlight different features. GIS provides database support that is designed to provide for the effective storage of spatial data. Furthermore GIS software provides a link between the interface and database to allow the user to easily query spatial data. However in terms of the widely accepted definition of a DSS, a GIS is not a complete DSS because of the almost complete absence of models or support for the organisation of models.

The construction of a specific DSS from GIS software is possible however, by incorporating models that make use of the GIS database and interface. In this context low end GIS and desktop mapping products may prove more manageable for applications design than full workstation based GIS systems. While these desktop systems lack the power of a full GIS, they may be able to make effective use of data which has been prepared for a specific purpose using a full feature GIS.

However some developments in GIS software since 1990 may make possible the use of standard software as the basis for an SDSS. An example of this type of software is the ArcView package from ESRI. As its name suggests, this software is primarily designed as to allow the user view and query spatial data. ArcView is available for the Windows, Macintosh and UNIX environments. It is intended that the full ARC/INFO package will be required for some GIS operations. ArcView has its own macro language; Avenue, the ability to interact with SQL database servers, and the ability to use platform specific links with other software. Together with its ability to support spatial queries, these characteristics make ArcView a potential generator for many types of SDSS software.

The incorporation in many GIS products of macro languages, such as Avenue in ArcView or Mapbasic in Mapinfo, facilitates their use to construct a DSS. In other cases GIS software allows the use of external procedures. Such linkages may not be entirely integrated, but nevertheless allow the useful combination of GIS software and models contained in external programs. An example of such software is found in Jankowski (1995), who discusses the integration of GIS software and multiple choice decision making (MCDM) techniques in a DSS. Routesmart (Bodin and Levy, 1994) provides vehicle routing functionality within the TransCad GIS.

The use of GIS as a DSS generator can make use of new facilities for interaction between software, techniques such as object linking (OLE), dynamic data exchange, and open database connectivity (ODBC). These techniques will allow data pass from the GIS to modelling software which can provide facilities not found in the GIS itself. Present software development trends suggest an object oriented future, in which small specialised applications, or applets, will be available for use as part of a larger package. In the Windows environment the development of such small applications will be facilitated by the use of development tools such as Microsoft Visual Basic or Borland Delphi. In this context the DSS generator, the GIS, will provide the main interface and database facilities, with applets used for additional modelling or interface requirements.

Conclusion

Given the advances in computer technology in general and GIS techniques in particular, I suggest that a growing subset of DSS applications in future will be those built using a GIS as a DSS generator. This class of DSS will make an important contribution, not because of its use of the latest technology, but because it will allow decision makers incorporate a spatial dimension in their decision making. This spatial dimension, which is not fully catered for in traditional DSS designs, is an important feature of many areas of DSS application. These potential areas of application including fields, such as routing or marketing, which have been important fields of DSS application in the past. The challenge for DSS builders is to achieve an appropriate synthesis of modelling techniques and interface and database approaches, drawn from the GIS domain, to provide effective decision support for these areas.

References

Alter, S., 1980 : *Decision Support Systems: Current Practice and Continuing Challenges*, Addison-Wesley, Reading, USA.

Angehrn, A. A., and Lüthi, H-J., 1990 : “Intelligent Decision Support Systems: A Visual Interactive Approach”, *Interfaces*, 20, 6, 17-28.

Armstrong, A. P., and Densham, P. J., 1990 : “Database organization strategies for spatial decision support systems”, *International Journal of Geographical Information Systems*, 4, 1, 3-20.

Bodin, L., and Levy, L., 1994 : “Visualization in Vehicle Routing and Scheduling Problems”, *ORSA Journal on Computing*, 6, 3, Summer 1994, 261-268.

Crossland, M.,D.; Wynne, B.,E., 1994 : “Measuring and testing the effectiveness of a spatial decision support system”, *Proceedings of the Twenty-Seventh Hawaii International Conference on System Sciences. Vol.IV: Information Systems: Collaboration Technology, Organizational Systems and Technology* Edited by Nunamaker, J,.F., Sprague, R.,H., IEEE Comput. Soc. Press, 1994.

Densham, P.,J., 1991 : “Spatial Decision Support Systems”, *Geographical Information Systems, Volume 1 : Principles*, edited by Maguire, D.J., Goodchild, M.F. and Rhind, D.W., Longman, 403-412.

Eom, H., and Lee; S., 1990 : “Decision support systems applications research: A bibliography (1971-88)”, *European Journal of Operational Research*, 46, 333-342.

Eom, S., Lee, S., and Kim, J., 1993 : “The intellectual structure of Decision Support Systems (1971-1989)”, *Decision Support Systems*, 10, 19-35.

Franklin, C., 1992 : “An Introduction to Geographic Information Systems: Linking Maps to Databases”, *Database*, April 1992, 13-21.

Gorry, A., and Scott-Morton, M, 1971 : “A Framework for Information Systems”, *Sloan Management Review* 13, Fall 1971, 56-79.

Grace, B. F., 1976 : “Training Users of a Decision Support System”, *IBM Research Report RJ1790*, IBM Thomas J. Watson Research Laboratory, 31 May 1976.

Grimshaw, D.J. 1994 : *Bringing Geographical Information Systems in Business*, Longman, 100-111

Jankowski, P., 1995 : “ Integrating geographical information systems and multiple criteria decision-making methods”, *International Journal of Geographical Information Systems*, May-June 1995, 9, 3, 251-73.

Keen, P., 1986 : “Decision Support Systems: The Next Decade”, *Decision Support Systems: a decade in persepective*, edited by McLean, E and Sol, H.G., North-Holland.

Keenan, P., 1995 : *Spatial Decision Support Systems for Vehicle Routing*, Working Paper MIS 95/10, Graduate School of Business, University College Dublin.

Maguire, D.J., 1991 : “An Overview and definition of GIS”, *Geographical Information Systems, Volume 1 : Principles*, edited by Maguire, D.J., Goodchild, M.F. and Rhind, D.W., Longman, 9-20.

Mallach, E.G., 1994 : *Understanding Decision Support Systems and Expert Systems*, Irwin., 428-435.

Muller, J-C., 1993 : “Latest developments in GIS/LIS”, *International Journal of Geographical Information Systems*, 7, 4, 293-303.

Sprague, R., 1980 : “A Framework for the development of Decision Support Systems”, *MIS Quarterly*, 4/4, December 1980.

Turban,E., 1995 : *Decision Support and Expert Systems 4th ed.*, Prentice-Hall International, 241-242.