Title
Unit 59 - Spatial Decision Support Systems

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Publication Date
1990

Peer reviewed

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A. INTRODUCTION

- multiple criteria methods allow for the presence of more than one objective or goal in a complex spatial problem
  - however they assume that the problem is sufficiently precise that the goals and objectives can be defined

- many problems are ill-structured in the sense that the goals and objectives are not completely defined

- such problems require a flexible approach
  - the system should assist the user by providing a problem-solving environment

- spatial decision support systems (SDSS) are designed to help decision-makers solve complex spatial problems

- GISs fall short of the goals of SDSS for a number of reasons:
  - analytical modeling capabilities often are not part of a GIS
  - many GIS databases have been designed solely for cartographic display of results - SDSS goals require flexibility in the way information is communicated to the user
  - the set of variables or layers in the database may be insufficient for complex modeling
  - data may be at insufficient scale or resolution
  - GIS designs are not flexible enough to accommodate variations in either the context or the process of spatial decision-making

- SDSS provide a framework for integrating: 1. analytical modeling capabilities 2. database management systems 3. graphical display capabilities 4. tabular reporting capabilities 5. the decision-maker's expert knowledge

- GISs normally provide 2, 3 and 4
  - the addition of 1 and 5 create a SDSS

B. DEFINITIONS AND CHARACTERISTICS

Decision support systems

- spatial decision support systems have evolved in parallel with decision support systems (DSS)
  - DSS developed for business applications (corporate strategic planning, scheduling of operations, etc.)

- DSS literature contains a substantial body of theory and a large number of applications
  - literature can be used to guide the design, development, implementation and use of SDSS
  - texts on DSS include: Bonczek, Holsapple and Whinston, 1981; Sprague and Carlson, 1982; and House, 1983

- many definitions of DSS require the presence of certain characteristics

- e.g. Geoffrion's definition requires 6 characteristics: 1. designed to solve ill- or semi-structured problems, i.e. where objectives cannot be fully or precisely defined 2. have an interface that is both powerful and easy to use 3. enable the user to combine models and data in a flexible manner 4. help the user explore the solution space (the options available to them) by using the models in the system to generate a series of feasible alternatives 5. support a variety of decision-making styles, and easily adapted to provide new capabilities as the needs of the user evolve 6. problem solving is an interactive and recursive process in which decision making proceeds by multiple passes, perhaps involving different routes, rather than a single linear path

- these characteristics also define a SDSS

- in addition, in order to effectively support decision- making for complex spatial problems, a SDSS will need to:
    - provide for spatial data input
    - allow storage of complex structures common in spatial data
    - include analytical techniques that are unique to spatial analysis
    - provide output in the form of maps and other spatial forms

C. SPATIAL DECISION-MAKING

- many spatial problems are complex and require the use of analysis and models

- many spatial problems are semi-structured or ill-defined because all of their aspects cannot be measured or modelled

Example: site selection for a retail store

- objective is to pick the site which will maximize economic return to the company

- return is affected by:
    - number of potential customers within market area
    - accessibility of the site (e.g. is it on a main street? is it possible to turn left into the site?)
    - visibility, signage, appearance
    - cost of site and construction

- some of these factors are difficult to evaluate or predict

- relative impacts of each of these factors on return may be unknown (except the last - direct cost)

- impossible to structure the problem completely - i.e. define and precisely measure the objective for every possible solution

- retail site selection problem is ill-structured

- a system to support retail site selection must be flexible
    - allow new factors to be introduced
    - allow the relative importance of factors to be changed to evaluate sensitivity or to reflect differences of opinion
    - display results of analysis in informative ways

- solutions to this class of problems often are obtained by generating a set of alternatives and selecting from among those that appear to be viable

- thus, the decision-making process is iterative, integrative and participative
  - iterative because a set of alternative solutions is generated which the decision-maker evaluates, and insights gained are input to, and used to define, further analyses
  - participative because the decision-maker plays an active role in defining the problem, carrying out analyses and evaluating the outcomes
  - integrative because value judgements that materially affect the final outcome are made by decision-makers who have expert knowledge that must be integrated with the quantitative data in the models

D. SDSS ARCHITECTURE

- Armstrong and Densham (1990) suggest that five key modules are needed in a SDSS: 1. a database management system (DBMS) 2. analysis procedures in a model base management system (MBMS) - defined later 3. a display generator 4. a report generator 5. a user interface

- to the programmer, this modularity facilitates software development
  - to the SDSS user, the system appears to be a seamless entity

overhead - SDSS architecture
  - one architecture for an SDSS is shown
    - the five software modules are represented by the boxes on the left of the diagram with the user interface, an expert system shell, encompassing the other modules
    - the arrows between the modules depict flows of data and information
    - the right-hand part of the diagram shows the interaction with the user who receives and evaluates output (alternative solutions) from the system which is either accepted as a solution or used to define new analyses

Data Base Management System

- GIS database management systems are designed to support cartographic display and spatial query

- database of an SDSS must support cartographic display, spatial query and analytical modelling by integrating three types of data: 1. locational (spatial primitives such as coordinates and chains) 2. topological (attribute-bearing objects, e.g. points, nodes and lines, and relationships between them) 3. thematic (attributes of the topological objects, including population, elevation, and vegetation)

- database must permit the user to construct and exploit complex spatial relations between all three types of data at a variety of scales, degrees of resolution and levels of aggregation

- database management systems found in many GIS use the relational data model

  - however, alternative data models have proved effective in applications of DSS
    - e.g. the extended network model is an enhanced form of the network model and is effective for representing the links and nodes of transportation networks
    - transportation networks are a popular base for developing SDSS because of the importance of applications for site selection and the abundance of methods of analysis

handout- Database for site selection

  - shows the implemented database for a site selection problem
    - locational component consists of COORD (coordinates), NODE and CHAIN
    - topological objects are the records POINT, L.A. NODE (possible site), LINE, STATE and CITY
    - thematic data are the six records on the extreme left of the diagram (LINE DISTANCE, LINE FEATURE, STATE DATA, CITY DATA, POINT FEATURE and NODE DATA)

- arrows between the records indicate relationships, both spatial and non-spatial, e.g.:
  - the 1:1 relation between NODE and COORD means that each node "owns" one coordinate
  - the 1:N relation between L.A. NODES and NODE DATA indicates that each possible site owns one or more sets of data
  - the N:M relation between CHAIN and COORD means that each chain is made up of many coordinates and that each coordinate can be part of more than one chain

- multiple relations of a given type are indicated by numbers beside the relevant arrows
  - L.A. NODE owns LINE in two relations, one indicates links to possible sites with lower identifiers, the other to possible sites with higher identifiers

- the system set is a construct that provides direct access to records so defined - there is no need to traverse intermediate record types as in other data models
  - e.g. it is possible to access a coordinate pair record (COORD) directly without accessing any other type of record

Model Base Management System

- one approach to incorporating analytical models in geoprocessing systems is to develop libraries of analytical sub-routines
  - permits large numbers of models to be made accessible very quickly, because existing programs can be patched into a system
  - wasteful in terms of replicated code

- second approach, used in business applications of DSS, is to develop a model base management system (MBMS)
  - consists of small pieces of code, each of which solves a step in an algorithm
  - as many of these steps are common to several algorithms, this approach saves large amounts of code

  - the system developer only has to modify one piece of code to update a step in several algorithms
  - the MBMS also contains information about how steps are sequenced to execute a given algorithm

- using an MBMS facilitates rapid development and testing of new algorithms
  - implementation may be achieved simply by adding a new formula to the MBMS
  - in other cases new code for additional steps also may be added to the model-base

Graphical and Tabular Report Generators

- should provide the following capabilities:
  - high-resolution cartographic displays
  - general-purpose statistical graphics, including two and three-dimensional scatter plots and graphs
  - specialized graphics for depicting the results from analytical models and sophisticated statistical techniques
  - the full range of tabular reports normally associated with each of the above

User Interface

- must be easy to use if they are to be effective in decision- making

- interfaces of many current GIS systems are modelled on those of business systems, using command lines, pull-down menus and dialogue boxes

- the move to graphical interfaces for operating systems provides an opportunity for system designers to develop more intuitive interfaces for geoprocessing systems

- by using a graphical display for communication between the decision-maker and the system:
  - icons can be used to represent system capabilities
  - the user can select parameters, data, output, etc., easily and intuitively
  - the user may be able to more easily visualize the processes represented within the model

E. DEVELOPMENT OF DSS

- Sprague (1980) presents a development framework
  - three levels of technological development
  - five functional roles

overhead - DSS development framework
  - depicts the three levels of technology and the five functional roles

Three levels of technology

- DSS technology ranges from simple, specific applications to broadly applicable systems:

1. a specific DSS is a system being used to address a specific problem

2. a DSS generator is a set of mutually compatible hardware and software modules used to implement the specific DSS

3. a DSS toolbox is a set of individual hardware and software items which can be used to build both DSS generators and specific DSS

- system vendors and consulting houses who must develop many different decisions systems of broadly similar nature on a recurring basis will build generators and toolboxes that can be adapted for individual clients with specific problems

Five functional roles

- the decision-maker is responsible for choosing, implementing and managing the solution
- the intermediary sits at a console and interacts physically with the system
- the DSS builder configures the specific DSS from the modules in the DSS generator
- the technical supporter adds capabilities or components to the DSS generator
- the DSS toolsmith develops new hardware and software tools
- these five roles may be filled by any number of people, individuals may have more than one function
- during the decision-making process, the decision-maker uses output from the system to evaluate interim solutions
  - the result of this evaluation may be a desire to investigate other aspects of the problem which may require new capabilities to be added to the SDSS
  - the system is updated as required by people filling the technical functional roles using the three levels of technology
- thus a process of system adaptation and evolution occurs rapidly during the decision-making process itself

F. CURRENT STATUS OF SDSS

- at this point, SDSS as defined here remains a conceptual framework rather than an implemented strategy
  - some systems approach a partial implementation of its concepts
  - several implementations of GIS in forestry have been described as SDSS but do not satisfy the full definitions used in this unit
  - SDSS is an important standard against which to measure spatial decision-making tools

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DISCUSSION AND EXAM QUESTIONS

1. Briefly describe the purpose and content of each of the five key modules of an SDSS.

2. Discuss the qualifications you think would be needed by individuals hired in each of the five functional roles discussed in this unit.

3. What kinds of analytical models might be included in an SDSS generator for each of the following applications:

monitoring of ground-water quality; emergency evacuation from around nuclear power stations; monitoring and fighting forest fires? Are there any similarities in these models?

Last Updated: August 30, 1997.