Chapter 4.2
Simulation Modelling within Collaborative Spatial Decision Support Systems Using "Cause-Effect" Models and Software Agents

Raja Sengupta
McGill University, Canada

ABSTRACT

Solutions to spatial environmental problems often require the integration of dynamic simulation models within GIS to create spatial decision support systems (SDSS) that can generate responses to theoretical "What if?" scenarios. Extending this paradigm to a collaborative spatial decision support system, however, faces significant challenges. This includes the inability of computationally intensive models to provide real-time results, and the inability of novice end users to effectively parameterize the models. Effective solutions to these problems proposed here include the use of "cause-effect" models to link inputs to outputs for a limited number of scenarios, as well as utilizing software agents that assist novice users in determining the correct input parameters for the models. Examples from the St-Esprit watershed SDSS serve to elucidate the proposed solutions.

INTRODUCTION

Sprague (1980) defined decision support systems (DSS) as computer software that are: (a) designed to solve the kinds of semi- and unstructured problems that upper level managers often face; (b) able to combine analytical models with traditional data storage and retrieval functions; (c) user-friendly and accessible by decision makers with minimal computer experience; and (d) flexible and adaptable to different decision-making approaches. Extending this definition, Armstrong, Densham, & Rushton (1986) used the term spatial decision support systems to refer to computer programs that help decision-makers solve semistructured spatial problems through the integration of analytical models, spatial data, and traditional geoprocessing software (such as GIS). Therefore, an SDSS supports the spatial decision-making process by providing access to models that help users assess the impact of alternative solutions on stakeholders in collaborative environments (Armstrong, 1994).

Several spatial decision support systems (SDSS) implementations have been proposed or demonstrated in literature that incorporates analytical modeling with traditional GIS software packages for decision support. For example, the NELUP DSS was developed to study the impact of policy changes (at a global, European, national, regional, county, or local level) on the rural landscape, agriculture, and environment using economic, hydrologic, and habitat models (Watson & Wadsworth, 1996). Another SDSS, which relocated supply stores for school districts, was developed to find the optimal number of regions and service locations within each region to serve a dispersed geographical pattern of demand (Armstrong, Rushton, Honey, Dalziel, Lolonis, De, & Densham, 1991). The "WaterWare" DSS was developed as a comprehensive SDSS to support the development of an integrated river basin management plan to resolve conflicting uses such as recreation, agriculture, water supply, and the environment (Jamieson & Fedra, 1996). And finally, faunal habitat and landscape ecology models are being increasingly integrated with GIS to support decision making at the landscape level (McGarigal & Marks, 1993; Larson & Sengupta, 2004; Zhu, Healey, & Aspinall, 1998)

However, current SDSS often act as a basic interface to complicated models, leaving the end user to figure out model input parameters on their own. Therefore, the execution of such models in the SDSS in real time creates three hurdles for end users of the SDSS:

1. The models are computationally demanding, and can take up system resources that essentially render them impossible to execute in real time;
2. Most SDSS expect the end user to be well versed with the input data requirements and critical parameters of the model, which requires scientific knowledge of the process being simulated; and
3. Most models integrated within SDSS aren't well suited to assisting a collaborative decision-making process, with the above two points creating significant complexity while running models in group settings.

In effect, the lack of real-time model runs forces the collaborative decision-making process to rely on preset examples and/or static map outputs of sophisticated numerical simulations. This limitation not only severely restricts the range of options that can be evaluated by the group, it also forces individuals to rely on third-party technical support for generation of key scenarios.

This chapter describes the development of two strategies that can allow dynamic simulation scenarios to be incorporated within an SDSS to make it capable of supporting collaborative research, namely (i) "cause-effect" models linking outputs to spatial inputs, and (ii) software agents to assist users in selecting and understanding model parameters and input variables. Taken together, these two approaches can be combined with traditional multicriteria analysis (e.g., analytical hierarchy process or AHP) and GIS-based overlay procedures, thereby providing multiple decision-makers access to real-time generation of "What if?" scenarios incorporating dynamic spatial process simulations and allowing for collaborative problem-solving (Jankowski, 1995).

The effectiveness of this procedure in creating the prototype of a collaborative planning tool is tested using the example of the St-Esprit watershed in Quebec. In the first part, "cause-effect" models of stream discharge linked to varied land use scenarios are generated using the Soil and Water Assessment Tool (SWAT) program. In the