INTRODUCTION TO SPATIAL DECISION SUPPORT SYSTEM

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Summary

Spatial decision making that deals with geographical problems has been around for quite some time. However, an interest in spatial decision support systems has grown more recently in importance, as more people with concerns about environmental, land use, natural resource, and transportation issues discover the benefits of geographical information. Many geographical decision problems are viewed as unstructured and laden with locational conflict. Spatial decision support systems offer a user-centered approach to deal with unstructured decision problems, by integrating predictive and prescriptive models with evaluation functions to assess the quality of the options being considered, and "what-if" capabilities to test alternative combinations of procedure and data. This form of computer-supported decision making has been developing steadily over the last two decades of the twentieth century, and its future prospects are significant.

1. Introduction

Spatial decision making is an everyday activity, common to individuals and organizations. People make decisions influenced by geography when choosing a store to shop in, driving a route, walking a path, selecting an entertainment locale, or opting for a neighborhood to live in, and so on. Organizations are not much different in this respect. They take into account spatial arrangements and distribution of resources when making a site selection, choosing land development strategy, allocating resources, and managing an infrastructure.

Most individual spatial decisions are made ad hoc, without a formal analysis. These decisions are often based on heuristics and internalized preferences (values). This expedient approach to spatial decision making can be explained by a relatively small "decision equity" at stake in daily decision situations, such as the selection of a place to shop or an entertainment venue. The cost of making a poor choice (decision) can be a smaller selection of goods, higher prices paid than elsewhere, or a boring evening spent at a nightclub. In contrast to these everyday decision situations faced by individuals, the decision equity for organizations is often quite high. Organizations are therefore more likely to use an analytical approach to support the decision-making process. This article explores the conceptual basis of spatial decision support system methodology applicable to decision problems involving high decision equity.

2. Perspectives on Spatial Decision Making

Just as there are different meanings attributed to spatial decision making, there are multiple perspectives on the nature of spatial decision making, including functional, tool, and organizational perspectives. Each of these three perspectives is outlined in the following sections.

2.1 Functional Perspective

From the functional perspective, spatial decision making might involve one or more of three time horizons: short-term operational, medium-term tactical, or long-term strategic problem perspectives. The difference among the short-term, medium-term and long-term approaches is usually a difference in the level of resources and commitment applied to the decision- making process. The resources can be both human and financial in character.

Short-term, operational decisions are often characterized by problem solving immediacy and routine management tasks. Examples of operational spatial decision would include: where the forest-fire-fighting crew should land, or at which location river-cleanup equipment is deployed following a sewage spill. Working with the crew and the equipment in place at the current time is the reality of the situation. Crews cannot be trained and equipment cannot usually be acquired overnight, unless they are borrowed from other governmental jurisdictions. The short time frame in which an operational decision often must be made precludes the application of predictive (that is, spatial interaction) and prescriptive (optimization) models. In such instances, spatial decision support will often be provided by computer maps (for example, in the case of a fire, a periodically updated map of the extent of the fire augmented by map layers representing the distribution of fire fighting resources, weather conditions, and forest roads), as well as database query functionality. This level of spatial decision support corresponds to a widely held view among the practitioners that decision-making support is synonymous with the access to decision-problem-relevant information.

Medium-term, tactical decisions commonly involve budgetary allocations for effective management of environmental or natural resource problems. Managing the spatial distribution of crews and equipment based on past fires or cleanup efforts can be a medium-term decision. In this case, one has time to allocate financial resources to various districts to change the spatial distribution of "potential response." In the case of forest-fire fighting, crew and/or equipment can be allocated among various regions to be prepared for events that might occur. In the case of sewage control, crews can be allocated to repair overflow problems in order to avoid future problems.

Strategic spatial decisions, in contrast to operational and tactical decisions, put higher demands on problem structure and analysis. Adoption of a long-term plan for an increase in the budgets for more human resources or more equipment, and where they might be located, is a strategic consideration. Deciding where to allocate the spill abatement equipment is not easy, but even more difficult if the alternative is cleaner water. Strategic plans often involve tradeoffs in infrastructure. Funding the fire-fighting service and sewer systems could be part of that tradeoff.

The three horizons to spatial decision making—operational, tactical, and strategic—might follow similar or different paths. For example, if we adopt a normative four-step process of intelligence, design, choice, and review, we can discuss differences in process due to horizon. Since operational decisions involve a limited amount of time, the intelligence, design, choice, and review process may be reduced to a few heuristic rules, because a quick response is often needed. The implementation of these rules can often be carried out using standard spatial and attribute query functions available today in every major geographic information system (GIS) software integrated with a problem domain database. In this sense one might consider GIS as a spatial decision support system.

Tactical decisions, longer in time frame, allow for more data intelligence from various sources. Also tactical decisions, similarly to strategic decision making, go beyond the immediacy of reacting to a decision situation and require a more careful consideration of how to allocate scarce resources. An example here can be a school district facing a severe budget cut. The temporal horizon of the decision problem (one year) and potential longer-term consequences put a decision of how to deal with the budget cut in the category of tactical decisions. The school district may analyze the decision situation by developing multiple scenarios of how to reallocate its resources in response to the imminent budget cut. The scenarios may include closing one of district's schools and various variants of student allocation to the remaining schools. Predictive and prescriptive spatial models (for example location/allocation models) can be used to develop the scenarios. This level of spatial decision support may require tools not commonly found in a standard GIS.

In strategic decision making, intelligence requires a careful problem definition, often involving many people, design entails the selection of evaluation criteria and search for feasible options (also called alternatives), choice requires the evaluation of many options among various participants of a group, and review assumes you have an opportunity to revisit the steps. In strategic decisions, the development of decision alternatives, computation of their impacts, and evaluation of alternatives often requires predictive/prescriptive modeling, spatial data handling, reporting, and visualization functions. Software systems integrating these functions have been called spatial decision support systems (SDSS).

2.2 Tool Perspective

The tool perspective illuminates the differences in commonly used perceptions of spatial decision support. For some practitioners, spatial decision support is synonymous with user-friendly and flexible access to decision-relevant data, stored in a spatially indexed database (that is, GIS database). Indeed, some tactical spatial decisions (for instance, allocation of forest fire fighting crews and equipment) can be fully supported by the results of GIS database query. For more on GIS database queries see ***Spatio-Temporal Information Systems*** **and** ***Spatial Query Languages.***

For others, spatial decision support involves an ability to perform “deep” thinking (for example, evaluation and interpretation) about a complex spatial problem, in an interactive and iterative manner, such that the decision maker(s) is facilitated in proceeding toward some single conclusion, or a series of conclusions. In this view, three formerly separate types of decision support are integrated into a spatial decision support system. These are cartographic visualization tools, spatial query tools, and analytical models. Computer mapping techniques implement cartographic visualization tools (see also ***Interaction Issues and Decision Support in Intelligent GIS).*** Spatially referenced data base management systems implement spatial query tools. Finally, decision analysis and spatial analysis techniques support analytical models. A spatial decision support system integrates these techniques in a computerized, analytical environment that supports decision makers in their search for solutions.

2.3 Organizational Perspective

The organizational perspective emphasizes the spatial decision making process and its actors. Until recently, spatial decision making was largely considered in terms of individual decision makers. This model has been validated in institutional spatial decision making by vertical organizational structures, sometimes referred to as “stove-piping” because of the narrow perspective it employs. In following the single-decision-maker perspective, many organizations have relied on an old and trusted model in which a decision maker is supported (“fed information”) by an analyst(s). The data analyst provides the decision maker with data reports, analysis results, and solution recommendations, and the decision maker acts upon them, making a decision. A good example of this model is a city GIS department supporting city government, other municipal agencies and their decision makers. In the traditional setting, a decision maker requests decision information in the form of tabulated data, maps, and analysis results. The information is extracted by a data analyst and delivered to the decision maker. There is little interaction between the decision maker and the analyst. The interaction, if any, is limited to a decision maker's request for information/data and the coordination of an analyst's work schedule with the decision maker's timeline.

A newer perspective is a participatory (group) decision-making model. This has recently evolved from trends in modern organizations towards flatter structures (fewer mid-level managers). Whether the decision process is internal to an organization or between an organization and outside parties, the process can involve many stakeholder groups convened to solve spatial decision problems such as land use allocation, site location, environmental restoration, and urban/regional development. The interest in participatory spatial decision making has been spurred not only by the trend towards flatter structures, but foremost by the realization that effective solutions for many spatial problems require a variety of expertise. Many spatial problems are labeled as poorly structured or difficult because they contain intangibles that cannot be easily quantified, their structure is only partially known or burdened by uncertainties, and potential solutions often become "not in my back yard" (NIMBY) controversies. These problems require the participation of people representing diverse areas of competence, political agendas, and social values. Also, from an organizational standpoint, the specialized division of knowledge and skills in many communities means that complex decisions are formed through consideration of multiple inputs by people tasked with various activities and responsibilities in different locations. As a consequence, diverse groups often must generate solutions to pervasive spatial problems. For more on these issues, see ***Advanced Geographic Information Systems.***

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Biographical Sketches

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