Framework for a Geographic Districting DSS using an Intelligent Object-oriented Model

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We describe a framework for a geographic districting DSS. The components included in the framework are an object-oriented geographic data model with built-in capabilities for storing spatial and non-spatial information pertaining to the geographic objects represented in the model; an intelligent spatial query processor that uses domain specific knowledge to reason over geographic data and process complex districting queries; and a knowledge acquisition tool that is used to capture domain specific knowledge. These components are combined together to create an integrated geographic districting DSS. We describe our data model, the rule processing subsystem in the model, and the knowledge acquisition subsystem in detail. Finally, we describe a pilot implementation based on the framework which uses real life census data and demonstrates how the system would work in practice.

An important and complex application area of Geographic Information Systems (GISs) is geographic districting. Districting is the process by which a certain area of land is divided into several pieces in order to satisfy certain needs. For example, an electoral district or school district may be drawn based on population size, composition of the population and other constraints. Geographic districting applications involve complex design issues using two dimensional and sometimes, three dimensional spatial data in conjunction with non spatial data. Typically, the characteristics of geographic districts are constrained by rules and regulations. An example of such a rule is: “A district must be compact and contiguous.” These rules and regulations could change over time, necessitating that corresponding changes be made to the structure of a district. Districts may also have to be redrawn due to changes in the population size or demographics. The process of redrawing districts is referred to as “redistricting.”

Redistricting is typically undertaken by community task groups, political groups, groups appointed by the judiciary, arbitrators, or a combination of all of these. Often, the members of these groups have individual agendas, and the redistricting process will involve negotiations and bargaining to accommodate disparate needs. The members also usually have diverse backgrounds and often do not possess the requisite knowledge to interact with large geographical database systems or knowledge management systems. There is a significant need, therefore, to make the redistricting process more efficient and easy through the use of computer based decision support systems (DSS).

Our paper describes a framework for a DSS for solving real life geographic districting and redistricting problems. Components within the framework include an object-oriented geographic data model, an intelligent heuristic query processor, and a knowledge acquisition tool. Acting together, these components support group knowledge acquisition and decision making.

This work draws on previous work done on a generic object-oriented geographic data model [Subramanian & Adam, 1993], [Subramanian, 1992], [Adam & Subramanian, 1992] and intelligent query processor [Subramanian & Adam, 1993b] by one of the authors. The current work incorporates the previous results and integrates it with the Fact-net method of knowledge acquisition [Randles & Elrod, 1992], [Ramakrishna & Brightman, 1986], to create a framework for
a geographic districting DSS. It is hoped that this framework, which meshes together important geographic districting concepts, and integrates generic components into a specialized DSS specific for geographic districting, will form the basis for future work in this important area.

**Geographic Districting: Some Issues**

Geographic districting applications involve, at the most basic level, the design and development of data models and query processing mechanisms that can be used to represent and interactively manipulate and query geographic objects with respect to a given set of constraints. A geographic districting DSS must also include additional features, such as mechanisms to facilitate data and knowledge acquisition and dissemination, tools for negotiations and other group support features, and a user-friendly interface.

The following are sample scenarios that illustrate the typical use of a geographic districting DSS:

- The users present certain constraints to the spatial (geographic) districting system and request the system to "make" districts using objects in the database that satisfy the given constraints. The system interfaces with a geographic database and returns a set of objects that can be made into a district.
- The users present a set of geographic objects to the system and inquire if the objects can be combined to form a district. The system returns "yes" or "no." If the system returns "no," then the users can present more objects, or subsets of the earlier set and ask the query again.
- The users present certain specific spatial and non spatial characteristics to the system, and request the system to retrieve geographic districts that have those characteristics. The system returns an appropriate response.

Several computer programs have been suggested in recent years to address the issue of districting. These are essentially single user, batch oriented programs written in BASIC, FORTRAN and Pascal. Some of these are reviewed by Wildgen [1989]. In Leech & Kandel (1990), Leech and Kandel discuss an intelligent system that automates the process of redistricting. Theirs is, however, an expert system with no notion of a database, a specific data model, interactive query processing or DSS features. Therefore, the system cannot be applied to large real life districting applications requiring real time interactive capabilities for a team (or committee) of users.

This paper attempts to address the gaps in the literature and provide a general framework for geographic districting DSSs.

**Components of Geographic Districting DSSs**

Before discussing the components of a geographic districting DSS, we would like to revisit the key requirements of a DSS, as detailed by Sprague and Watson in their seminal "framework for DSSs" [Sprague & Watson, 1986]. Their framework organizes DSSs into two major parts. The first part pertains to:

- The three levels of technology used in developing DSSs
- The developmental approach for the creation of a DSS
- The roles of key types of people in building and using a DSS.

The second part deals with evaluating the performance of DSSs.

The “three levels of technology” mentioned above pertains to the three approaches adopted in the actual development of a DSS — namely, i) a “specific” approach where a stand-alone application is developed in order to provide tools to amplify a manager’s judgment; ii) a “DSS generator” approach which combines a set of tools which provide the capability to quickly and easily build a specific DSS; iii) the “DSS Tools’ approach which are hardware and software elements that facilitate the development of a specific DSS or DSS generator.

In this work, we use the “DSS generator approach” which combines a set of tools to create a specific DSS. In addition, we also take a developmental approach in actually creating some of the key components of the DSS. We propose that a DSS for geographic districting must consist of the following components:

- A highly robust spatial data model that can store and organize spatial (as well as non spatial) data. This will include the data subsystem, the model subsystem and a knowledge subsystem (to store domain specific knowledge that may change over time).
- A query processing mechanism that can intelligently process complex and iterative spatial queries using the knowledge stored in the system.
- A tool (or tools) to acquire domain specific knowledge that will be stored within the data model and used by the query processor. This will also include a generic GDSS whose role will be to facilitate negotiations (as to what knowledge requires to be captured and stored in the system) and iterative data gathering and refinement among the members of the districting group.

In addition, the DSS must also include a user interface that will enable users of the system to access and manipulate the system with ease. The three components (in the previous paragraph) must, therefore, be seamlessly integrated so that the end user sees one user-friendly interface and not the individual components.

Each of the components possess certain specific characteristics which are discussed below.
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