

Chapter IX

Map Overlay Problem

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ABSTRACT

Maps usually contain data from different sources (e.g., population, natural resources, cities, roads, infant mortality rate, etc.) When all the information is compiled it is almost impossible to distinguish a certain type of data from the rest. Geographic Information Systems (GIS) usually organize maps into layers, each representing an aspect of the real world (de Hoop et al. 1993). Layers form thematic maps of a single type of data, allowing users to query each one separately.

INTRODUCTION

The main purpose of a GIS is to analyze geographic data. As map information is organized into layers, it is necessary to overlay the thematic maps involved whenever we need to query data

that relates to various layers (e.g., which regions with population larger than one million have infant mortality rate lower than a certain value?). Each thematic map can be seen as a partition of the plane into regions determined by points and lines. **Overlaying** two or more maps generates a

new map containing information about the relationship between them. Thus, overlaying is one of the most important analysis operations in GIS, allowing complex queries that can not be applied to the original layers separately.

Applications

There are many uses derived from overlaying subdivisions of the map, such as:

- Overlaying layers of geographical data in order to perform queries involving several layers.
- Area interpolation: given the population of a region A that overlaps a region B , estimate B 's population, assuming that it is proportional to the area of A that is covered by B .
- Boolean operations among polygons: union, intersection, difference.
- *Windowing*: operation for which a window is overlaid over the map and everything outside of the window is eliminated.
- Buffering: it is made around points, lines and polygons. If the *combined buffer* of several elements is needed, it is done as a **polygon overlay**.

PROBLEM DESCRIPTION

The *Map overlay* problem is the overlay of several input maps into a single output map. A map is a 2D spatial data structure, which is compounded by nodes (2D point where two or more lines intersect), chains (connected set of segments that start and end on two nodes), and regions (connected subset of the plane with polygonal boundary) that create a plane subdivision. The output map contains all the nodes in the input maps plus the nodes generated by the intersections of the chains of both maps together. The chains of the input maps are interrupted at the intersection points creating

the output map's chains; hence, the output map contains new regions defined by the intersections of the input regions. The *map overlay* problem consists of generating and relating the structures of the output map (Wu, 2005).

The process of obtaining the output map can be divided into four steps (Wu, 2005):

1. Determine the new nodes at the intersection points of the input chains.
2. Form the new chains by splitting the chains at the new nodes.
3. Form the new regions, and solve the containment of boundaries.
4. Determine the overlay relationships between the regions of the output map and those of the input maps.

The first step is the most time consuming. In order to improve its performance, many algorithms based on spatial analysis and computational geometry techniques, have been developed.

STATE OF THE ART

A Brief History

A naive algorithm for overlaying maps would take each segment of one map and compare it with all the segments of the other looking for intersections. If each input maps have $O(n)$ segments, the algorithm runs in $O(n^2)$ time. But, this is low performance for the most typical input sizes (over 100,000 points). To improve the time it is convenient to follow a local processing principle, which means not checking for intersections between segments of distant regions because they do not intersect. It has been proven that a lower bound for the problem of finding all the intersection points between a set of n segments is $\Omega(n * \log n + k)$, where k is the number of intersections, and it can be achieved using $O(n)$ space.

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