

# Extending Ordinary Planar-Graph-based Spatial Data Model with Voronoi Approach

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## (Extended Abstract)

### 1. Introduction

Most of current GIS systems are based on the planar graph-based spatial data model where spatial entities are represented as points, line and polygon objects [Worboy, 1992]. The use of the planar-graph does not imply a vector data structure, but provides us with concepts of O-cells, I-cells, 2 cells upon which topological relationships such as enclosure, connectivity and contiguity are described and represented [Lee, 1991], as shown in Fig. 1. Some special topological data structures have been developed to represent these topological spatial relationships [Laurini and Thompson, 1992]. For instance, a link-node list showing from- and to- node labels can be used to represent the connectivity with a separate table for the coordinates of the lines. The contiguity may be directly addressed by a table of lines with data items for left and right polygons, and a separate table for coordinated for the lines. Another contiguity matrix may also be constructed for facilitating spatial access. Containment can be dealt directly via a hierarchical organization and special codes.

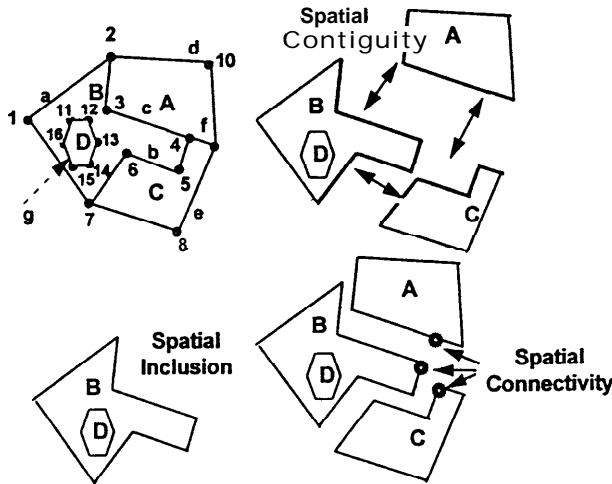


Fig. 1 Three major topological relationships maintained in current GISs

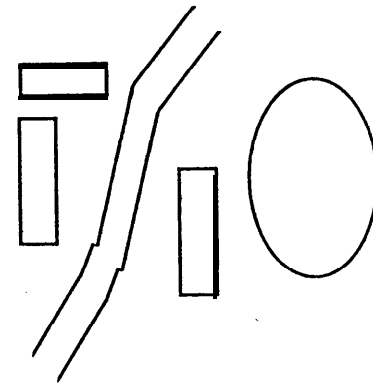


Fig.2 Lateral adjacency between spatial entities

The topological data are redundant from a database point of view because they can be derived from the geometric data. In addition, not all topological properties could be represented

directly with the concepts of boundaries and interiors of ceils. Some topologically structured databases may be dealt with only one, or no all, properties explicitly; and not all situations can be easily handled topologically [Laurini, R. and D. Thompson, 1992]. For example, the playground in Fig.2 is spatially adjacent with the road and the buildings, but they do not have common edges or points. In order to determine the lateral adjacency, a polygon should be formed for representing the playground and line-intersection approach would be used, which is often time-consuming.

It was found by C. M. Gold that the lateral spatial relationship could be easily described and represented by the Voronoi diagram of the point, line and polygon objects [Gold, 1989]. Each spatial object has its own Voronoi region which defines implicitly the spatial adjacency with the adjacent objects (or the “influence area” of the objects). It is therefore becoming natural to extend the ordinary planat-graph based model with the Voronoi approach. The basic idea in this paper is to partition the space under consideration into Voronoi tessellation with point, line and polygon objects, and to integrate the Voronoi tessellation with the ordinary planar- graph based topological data.

## 2. Reflecting adjacent relations with Voronoi tessellation

Voronoi diagram is one of the most fundamental data structures in computational geometry [Aurenhammer, 199 1]and another spatial model which poses a variety of challenges to the ‘usual way of doing things’ in GISs [Gold, 1994]. It is a space-filling topological structure, where the whole space is subdivided into a set of tiles (or regions) according to the distribution of the objects. Each object has its own ‘influence region’ (or Voronoi region) containing all locations closer to that object than to any other.

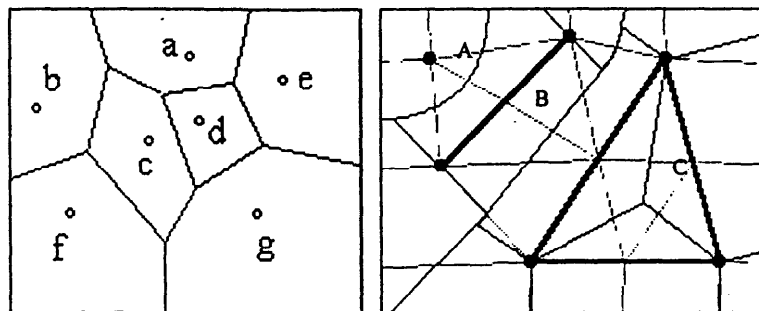


Fig. 3 Voronoi tiles of point, line and area objects

VORDLL, a special Voronoi Dynamic Linking Library developed by C.M. Gold and Weiping Yang [Gold and Yang, 1995] was used for generating the Voronoi tiles as shown in Fig.3. The basic topological elements in VORDLL are the Vpoint and Halflines (Fig.4). Each spatial object may consist of several Vpoints and Halflines. For example, the line object  $NLS_2$  in Fig. 5 is associated with two Vpoints  $vN_2, vN_3$  and two Halflines  $vLHL_4, vRHL_5$ . The area object

$NA_3$  is associated **with** two Vpoints  $vV_6, vV_7, vV_{10}$  and six Halflines  $vLHL_8, vRHL_9, vLHL_{11}, vRHL_{12}, vLHL_8, vRHL_9$ .

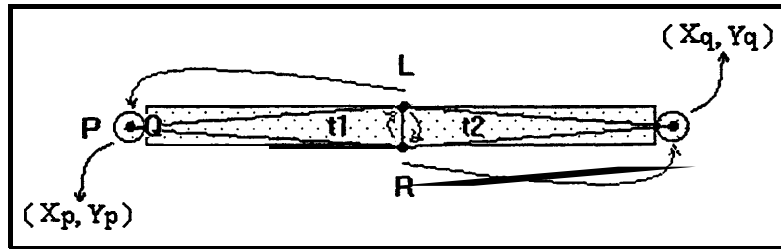


Fig. 4 Vpoint and Halflines in the VORDLL

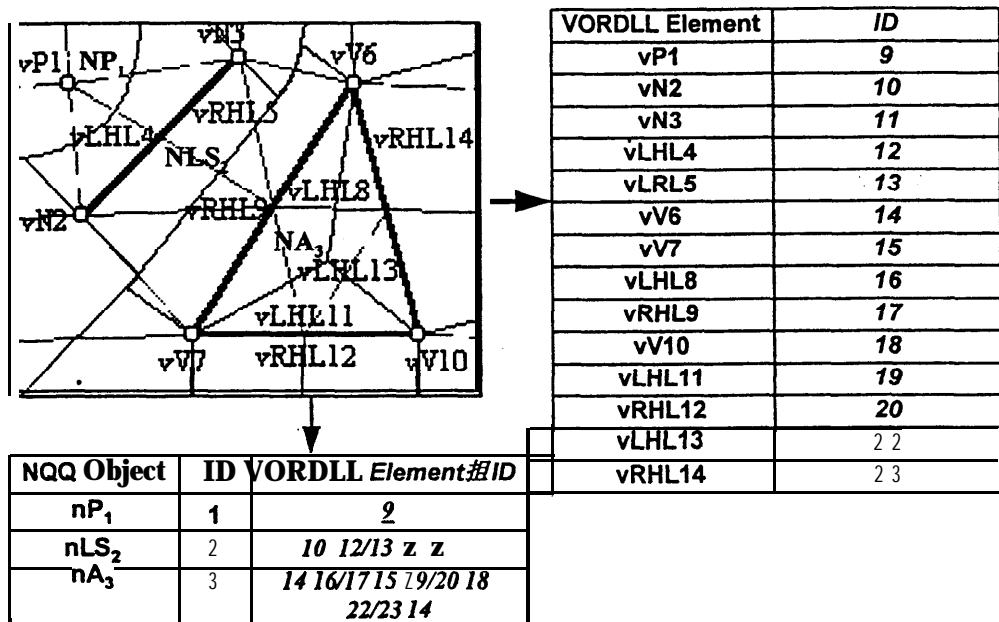


Fig.5 VORDLL elements associated with spatial objects

The adjacent relationships between the spatial objects are reflected from the tessellation and are represented by the dual, Delaunay triangulation. For instance, the adjacent area object  $NA_3$  and line object  $NLS_2$  share a common Voronoi edge which is reflected by one edge of its dual Delaunay triangulation. By identifying the existence of such an edge of Delaunay triangulation, it is possible to determine if the two objects are spatially adjacent.

### 3. Extending ordinary planar-graph based model with Voronoi diagram

In order to extend the ordinary planar-graph based data model, the Voronoi tessellation of spatial objects is integrated with the ordinary point, line and polygon data. The resulted Voronoi tessellation-based Entity-Category-Relationship (VECR) model is shown in Fig.6, which represents the spatial entities and the spatial connectivity, contiguity, enclosure and lateral adjacent

relationships.

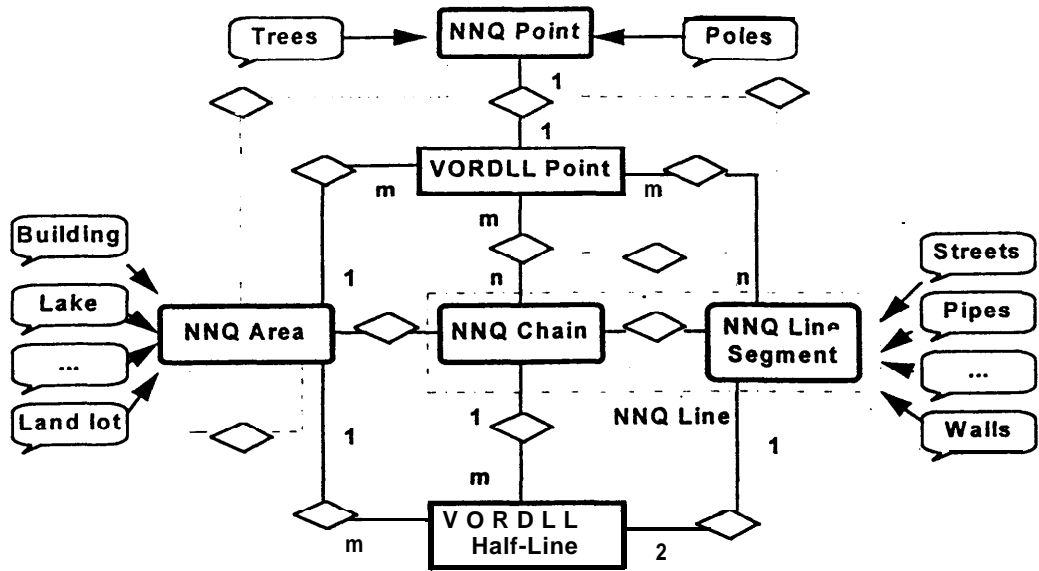


Fig. 6 Conceptual Voronoi E-C-R model

Logical data modeling of the Voronoi E-C-R model was developed for representing the data records and experimented under the Windows environment with VORDLL.

#### 4. Nearest neighbourhood queries based on the VECR model

The operators for nearest neighbourhood query was defined and analyzed for the point, line, chain and area objects in Voronoi E-C-R model, such as ImmeNeighbor, Nearest, SecondNearest, LateralNeighbor and TraceNeighbor (Table 1).

Table 1 Nearest neighbourhood query operators for elements in Voronoi E-C-R model

Operators	nP	nLS	nC	nA
ImmeNeighbor	ImmeNeighbor_nP	N/A	N/A	ImmeNeighbor_nA
Nearest	Nearest_nP	N/A	N/A	Nearest_nA
SecondNearest	SecondNearest_nP	N/A	N/A	N/A
LateralNeighbor	N/A	LateralNeighbor_nL S	LateralNeighbor_nC	N/A
TraceNeighbor	N/A	TraceNeighbor_nLS	TraceNeighbor_nC	N/A

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