REPRESENTING AND QUERYING SPATIAL NETWORKS IN DATABASES

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Outline

1. Motivation

2. Current Approaches to Implement Spatial Network

3. Spatial Network Data Model

4. User View of Spatial Network

5. Spatial Network Query Language

6. Conclusion

What is a Spatial Network?

- Eg. Road Networks, River Networks, Pipeline Networks
- Any Network which is characterized by a spatial embedding is known as *spatial network*
- Spatially embedded and labeled (I75, Speed Limit = 30miles per hour) graphs created by the interconnection of spatial elements like spatial lines and spatial points
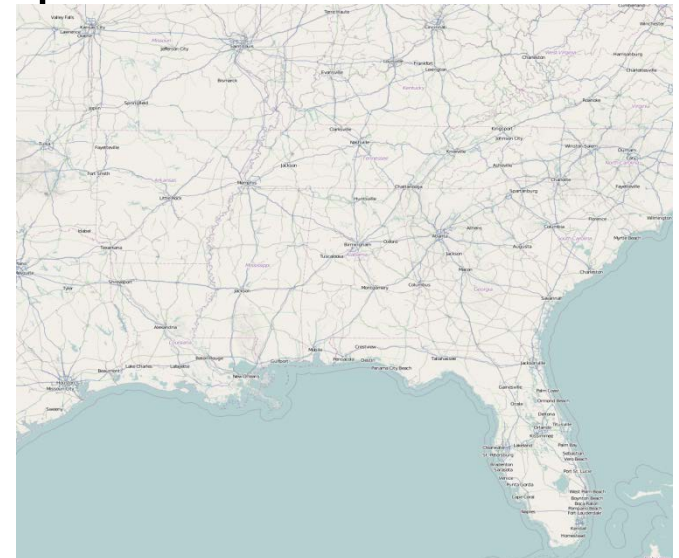
What is a Spatial Network? (contd.)

- Spatial Networks play a fundamental role in disciplines like geography and cartography

- Geographers commonly encounter problems involving flows in constrained environments like networks

- Transport, navigation assistance systems, and traffic forecasting and city planning

- Spatial network analysis is important in land use planning and city planning for establishing water ways, power grids and planning transport systems

Why Do we Need Database Support?

- Increasing use has led to a huge increase in the generation of spatial networks data (OpenStreetMap data : 21 GB data, weekly changeset: 500 MB)

- Databases support is essential to store the huge volumes of spatial network data and to utilize them in various GIS applications in an efficient way

- A standard, and extensible method of storing, querying, and analyzing the spatial network data is required

Current Approaches for Spatial Networks

- Graph Based models
  - Built around nodes which are zero-dimensional entities and arc which are one-dimensional entities
- Partial Geometry Based Models
  - Each vertex of the graph is associated with a spatial embedding
- Pure Network Models
  - Pure geometry based models for spatial network
  - Incorporates thematic data as well

Current Approaches for Spatial Networks

- Commercial Approaches
  - ESRI's ArcGIS
    - Has specialized model
   - Middleware layer called *GeoDatabase* along with commercial RDBMS
  - Oracle Spatial Network Data Model
    - Graph based model with a node table, link table, and metadata table
    - Access and modification can be performed by provided Java APIs

Limitations of Current Approaches

- Limitations in Modeling
  - No three dimensionality
  - No spatial network predicates
- Limitations in Implementation
  - Network Data scattered over numerous tables
  - Middleware layer required
  - Loss of database features like concurrency, data recovery etc.
  - No standard querying support

Limitations of Current Approaches
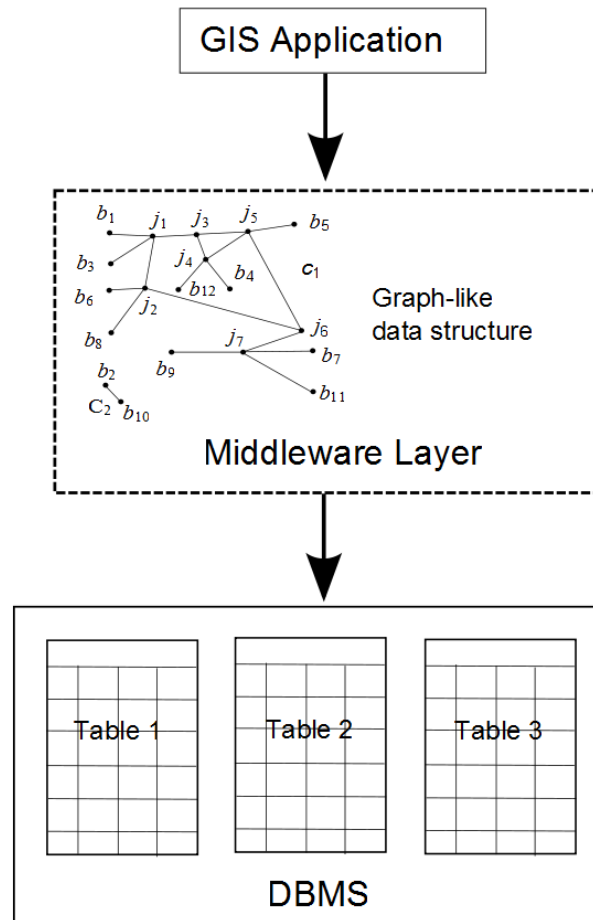
Goal of our Project

The goal is to design, define, and implement a data model for spatial networks and incorporate it in a database context
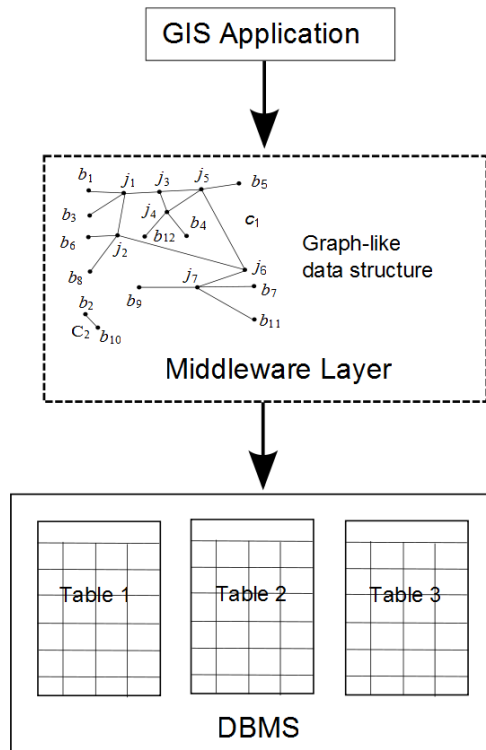
- Architecture
  - Incorporate spatial network data type in spatial database as a single object
  - All operations and predicate evaluation happens inside the database
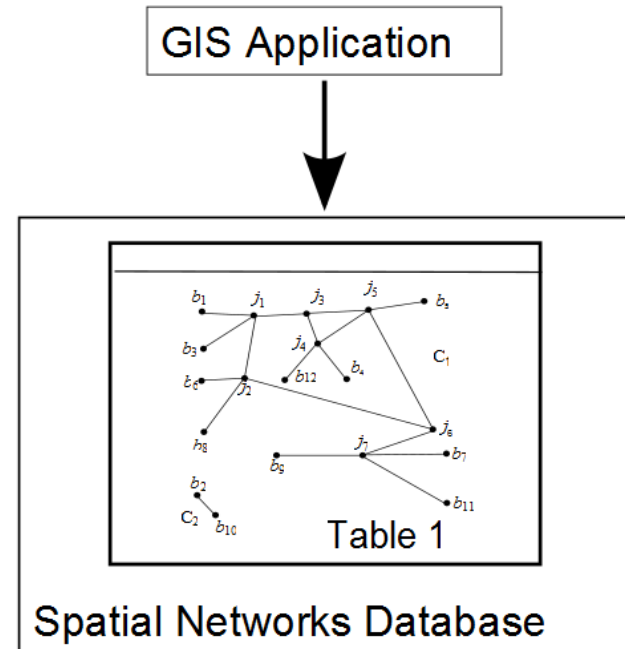 - Release GIS application developer of data management duties

Goal of our Project

- Conceptual view
  - View spatial network as a single abstract data type
  - Spatial network as the first class citizen of the database
  - Access, query, and manage the spatial network data using standardized query language

Architectural Change

(a)   (b)

Figure: Current architecture of Spatial Networks Database (a) and proposed architecture (b)

The Spatial Network Data Model

- ☐ Channel
- ☐ Junctions
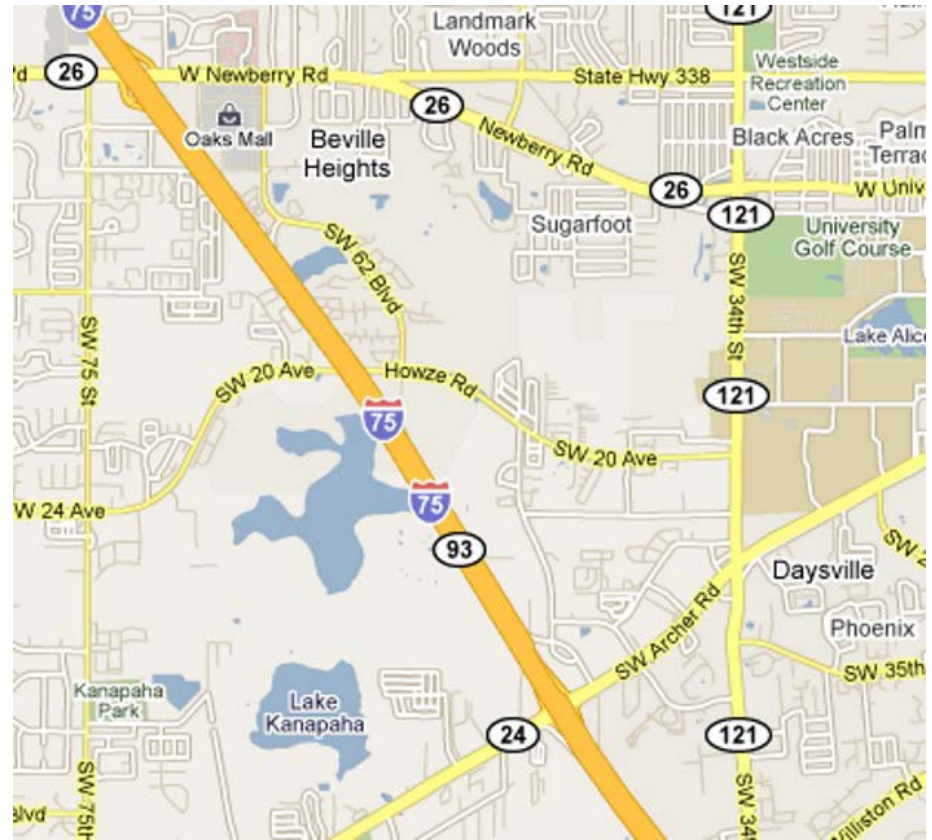- ☐ Boundary Points
- ☐ Access Points
- ☐ Labels

Figure: A Road Network

What are Spatial Network Operations?

- The operations are separated into *inter-network* operations and intra-network operations
- Five classes of operations have been identified:
  - Basic Operation (eg. Length)
  - Auxiliary Operation (eg. Directly Connected Channels)
  - Retrieval Operations (eg. Window)
  - Metric Operations (eg. Node Centrality)
  - Network Set Operations (eg. Network Union)

Spatial Network Predicates

- Predicates in spatial network has not been studied according to our knowledge

- Spatial predicates are used as filter conditions in spatial selections and spatial joins

- Topological predicates characterize the relative position of two spatial network that are preserved under certain continuous transformations including all affine transformations.

Spatial Network Topological Predicate

☐ "Which roads *cross* the river Mississippi?"
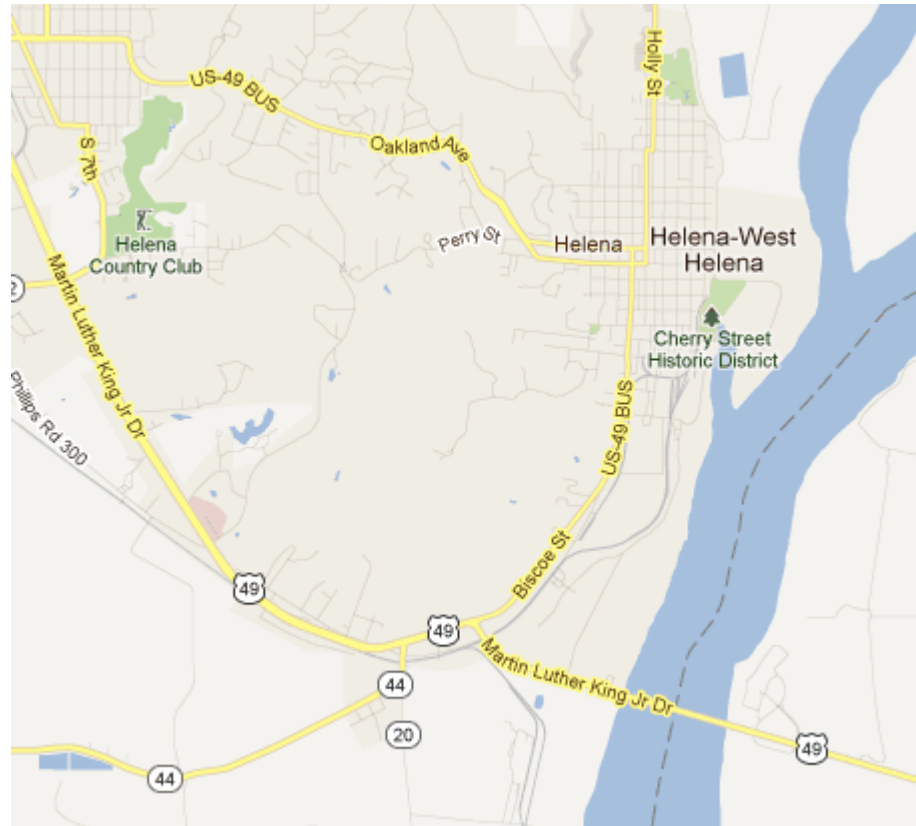
User View of a Spatial Network

- Spatial Networks are directly stored in databases as stand-alone entity as table attribute type *snet*

- An entire snet object including the geometry, topology and attributes is stored as a single object in the database

- This mechanism avoids the need for making objects of *snet* data type dependent on multiple tables

- Spatial network becomes the *first class citizen* of the database

User View of a Spatial Network

Network_type:string	Administered_by:string	Road:snet
"Interstate"	"Federal"	Interstate_hwy
"Country Roads"	"State"	Country_rd
"Single Carriageway"	"State"	S_carriageway

Table 1: Table Structure and Tuples from *RoadNetworks* table

Spatial Network Query Language

- Spatial Network Definition Language
- Spatial Network Manipulation Language

Spatial Network Definition Language

CREATE LABEL roadLabel**(**id_attr **string** l; speed_limit **real** l**);**
CREATE SNET road(roadLabel)**;**

      ADD CHANNEL 13th_Street
      INTO road
      AS l1;

      ADD ATTRIBUTE speedlimit
      IN 13th_Street VALUES (0.0 0.2 40;
                          0.2 0.7 50;
                          0.7 1.0 40);

Spatial Network Manipulation Language

□ Four classes of queries have been identified

    ◻ Network Queries

> **select** *Intersection*(N.road, M.road)
> **from** RoadNetworks as N, RoadNetworks as M
> **where** M. Network_type = `Interstate' and N. Network_type <> `Interstate'

    ◻ Component Queries

> **select** ShortestRoute**(**N**.**road, p1**,** p2**)**
> **from** RoadNetworks as N

Spatial Network Manipulation Language (contd)

- ## Component Attribute Query

  select G.sectorName, avg(GetAttribute(sn, number, capacity)
  from RoadNetworks as G, GetAllChannels(G.Grid)
  group by G.sectorName

- ## Network Attribute Queries

  select N.RoadType, N.administered_by
  from RoadNetworks as N

Conclusion

- The spatial network data model is an abstract data model as a specification for later implementation

- Spatial Network is stored in a database as a single object instead of being spread across a number of tables

- Spatial network becomes a first-class citizen of the database

- Users have a standard flexible querying support for spatial network.