Outline

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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 = 30 miles per hour) graphs created by the interconnection of spatial elements like spatial lines and spatial points
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

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.
“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

<table>
<thead>
<tr>
<th>Network_type: string</th>
<th>Administered_by: string</th>
<th>Road: snet</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Interstate”</td>
<td>“Federal”</td>
<td>Interstate_hwy</td>
</tr>
<tr>
<td>“Country Roads”</td>
<td>“State”</td>
<td>Country_rd</td>
</tr>
<tr>
<td>“Single Carriageway”</td>
<td>“State”</td>
<td>S_carriageway</td>
</tr>
</tbody>
</table>

**Table 1:** Table Structure and Tuples from *RoadNetworks* table
Spatial Network Query Language

- Spatial Network Definition Language
- Spatial Network Manipulation 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);
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
```
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.