State of the art of FOSS4G for topology and network analysis

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FOSS4G 2010 - Barcelona
Oslandia, who's that?
Oslandia

Young French SME specialised in Open Source GIS

**PostGIS experts**: Vincent Picavet & Olivier Courtin

Mainly Focuses on:
- **Spatial Databases** (PostGIS, SpatiaLite)
- OGC, ISO, INSPIRE **Standards** and **SDI architecture**
- **Complex analysis**: Routing, Network and Graph Solutions

Oslandia's ecosystem:
Oslandia's Technologies

3D  GDAL  GEOS
GRASS  GraphServer  INSPIRE  MapServer

OGC  PgRouting  PostGIS

PostgreSQL  Spatialite  TinyOWS

TileCache  PyWPS  QGIS
Oslandia, Find us at FOSS4G

Running long and complexes processes with PostGIS
Vincent Picavet, Wednesday - 12h00 – Sala 6

PostGIS meets the third dimension
Olivier Courtin, Wednesday - 12h30 – Sala 6

State of the Art of FOSS4G for Topology and Network Analysis
Vincent Picavet, Thursday – 14h30 – Sala 5

Breakout Session: Spatial Databases
Code Sprint on Friday: PostGIS

Oslandia : Bronze Sponsor
Presentation plan

- Introduction
- What is topology?
- What is Network Analysis?
- FOSS4G for topology & NA
- Conclusion
- Perspectives
- Questions
Introduction
Back to the roots

Problem of the seven bridges of Koenigsberg

Topology and graph theory was born!
Not so long ago...

- 4 colors map
  - «Given any separation of a plane into contiguous regions, producing a figure called a map, no more than four colors are required to color the regions of the map so that no two adjacent regions have the same color»

- Conjecture in 1852 (Francis Guthrie)
- Proof in 1976
- First computer-assisted proof
- GIS Problems lead to complex theoretical issues
Nowadays GIS application fields

- Transportation networks at large
  - Path finding & Routing
  - Network flow
  - Fleet management
  - ...
- Resource allocation
- Crisis management
- Hydrology
- Computer networks
- Geomarketing
- Mobile applications
- ...

[Image of a street sign with various directions]
What is topology?
Topology – General

General:
- «Area of mathematics concerned with spatial properties that are preserved under continuous deformations of objects»

GIS:
- «Spatial relationship between geographic features based on location»

Implicit on maps: eye-brain system interprets it

Needs to be explicit for computer systems

Relations
- Connectivity, Adjacency, Containment, Proximity, Relative Directions

Rules based on relations
Classic feature model

- aka «Spaghetti model»
- 1-1 translation of analog map
- Line = series of ordered (x, y) points
- Polygon = closed loops define boundaries
- Different lines/Polygons = independent objects
- No explicit connectivity & neighbouring info
- Simple and efficient
  - Cartographic display
  - Used by most CAD DB
Why topology?

- Insure correct boundaries
- Enhance analysis
- Insure data quality
- Topological editing and digitizing
- Needed to do network analysis

Get rid of the Spaghetti Monster!
Your very own topology
- Feature-attribute based
- Use relations and create rules

Classic topology model
- Node, arc/edge, face
- Connectivity, Direction, Adjacency

Most GIS data format → no topology
- Except: ArcInfo Coverage, TIGER, DLG, OSM (partly)
From spaghettis to topological zen

- Multiple ways to build topology from geometry
- Build your own model or use a standard one
- Classic build process steps
  - Extract all shared vertices as nodes
  - Create edges between nodes (lines & polygon boundaries)
  - Create faces with edges (polygons)
- Data cleaning
  - Automatic
  - Semi automatic
  - Manual

Clean & Validate with topology rules
Standardization

- Main standard, DB-oriented:
  - BS ISO/IEC 13249-3:2006 aka SQL/MM
- Defines model and operations
- Node-edge-face model, with geometry
  - ST_NODE, ST_EDGE, ST_FACE views
- ST_CreateTopoGeo, ST.ValidateTopoGeo
- Editing functions
- Topology-network model and operations
  - Creation, validation, editing
  - Shortest Path
What is Network Analysis?
Graph Theory – Network theory

- Graph Theory:
  - «Study of graphs: mathematical structures used to model pairwise relations between objects from a certain collection.»

- Networks
  - Nodes & Edges
  - Directed / Undirected
  - Weighted or not
  - Definition varies...

- Social Networks, Biology, Link analysis, centrality measures...
Some network analysis problems

- Enumeration
- Sub-graphs
- Colouring
- Routing
  - Minimum spanning tree
  - Route inspection problem
  - Shortest path problem
  - Steiner tree
  - Travelling salesmen problem
- Network flow
- Visibility graph
- Covering problems
- Graph classes
FOSS4G Tools
FOSS4G Softwares

- PostGIS
- PgRouting
- GvSIG
- GraphServer
- Spatialite
- GRASS
PostGIS

- SQL/MM Topology Model
- Partial implementation
  - No network analysis
- Node-Edge-Face
- Create, Validate
- Raw edit
- SQL/MM interface for editing, Geo/topo operations

```
SELECT topology.CreateTopology(name, [srid], [tolerance [srid]], [tolerance]);
SELECT * FROM topology.ValidateTopology(name) ; -- topology validation

INSERT INTO mytopology.edge … ;
INSERT INTO mytopology.face … ;
INSERT INTO mytopology.node … ;
SELECT ST_AddIsoNode(…) ;
SELECT ST_ChangeEdgeGeom(…);
SELECT topology.Geometry(TopoGeometry) ; -- get geometry from topology object
SELECT topology.DropTopology(name) ;
```
PgRouting

- PostGIS Plugin
- Own network model
- Shortest path
- Driving distances
- Travelling Salesman Problem
- Algorithms
  - Dijkstra
  - A*
  - Shooting star (with restrictions)
- Network building tool & OSM import tool

SELECT * FROM shortest_path_astar('SELECT gid AS id, source::int4, target::int4, length::double precision AS cost, x1, y1, x2, y2 FROM dourol' , 3, 7, false, false);
GvSIG – Topology extension

- Full topology management
- Multi-Layer topology builder
- Set of topology rules system
  - Complex parameterized rules
  - Multi-layer rules
- Topology validation & partial validation
- Topological digitizing
- Topology exceptions management
- Automated, semi-automated and manual cleaning
- Full GUI
  - Native GvSIG integration
- Geoprocessing
  - Generalization, Voronoi, Poly2lines, clean, translate...
Verificando topología

Verificando reglapolygon must be closed: 0 de 0

Reglas de la topología:

Primera capa que interviene en la regla
Infraestructuras_Hidráulicas.shp

Segunda capa que interviene en la regla
Sistemas_de_Explotación.shp

Reglas: [Añadir regla, Eliminar regla, Eliminar todos]
Capas: [Aceptar, Cancelar]

Todo extremo de una línea debe tocar a otro extremo de línea o a sí mismo.
GvSIG – Network extension

- Network Analysis
- Topology builder
  - Save / reload function (specific format)
- Interactive GUI for network management
- Algorithms
  - Shortest path
  - Connectivity
  - Minimal spanning tree
  - Origin/destination matrix
  - Finding providers for events
  - Service zone
GvSIG – Network extension

Informe de la ruta calculada

Distancia acumulada: 0,06

Mostrar en el mapa

16. Siga PLAZA CAGANCHA durante 0 y gire a la Izquierda por AV GRAL RONDEAU
Distancia acumulada: 0,06

Mostrar en el mapa

17. Siga AV GRAL RONDEAU durante 0 y gire a la Derecha por MERCEDES
Distancia acumulada: 0,06

Mostrar en el mapa

18. Llegada a: MERCEDES
Distancia acumulada: 0,07
GraphServer

- Standalone routing server
- Algorithms
  - Shortest path (Fast Dijkstra implementation)
  - Driving distances
- Focus on multimodal and GTFS data integration
- OSM import tool
- HTTP interface
- Highly customizable
  - C core
  - Python library
  - Hooks to use as a framework
- Own SQLite data format
- Used in production (Trimet, MapQuest...)
Spatialite

- SQLite-based embedded spatial database framework
- Routing functionalities
- SQL interface
- Network building tools (with GUI)
- Query GUI
  - integrated with Spatialite GUI
- Algorithm
  - Shortest path (Dijkstra)
**GRASS**

- Native N-E-F topology
  - Built automatically
  - Supports digitizing
  - Cleaning module & network maintenance (v.clean, v.net)

- Graph & network analysis modules
  - Through DGLib (Directed Graph Library)

- Algorithms
  - Shortest path (v.net.path, d.path, v.net.timetable)
  - TSP (v.net.salesman)
  - Resources allocation (v.net.alloc)
  - Minimum Steiner trees (v.net.steiner)
  - Iso-distances (v.net.iso)
  - Connectivity (v.net.connectivity)

- Grass GUI
- Scriptable
Frameworks

- Boost Graph Library
- Parallel Boost Graph Library
- R - igraph
BGL & PBGL

- Boost Graph Library
  - «standard» C++ library
  - High quality & highly customizable
  - Efficient algorithms

- Implements
  - Shortest Path (Dijkstra, Bellman-Ford, Johnson)
  - Minimum Spanning Tree (Kruskal, Prims)
  - Connected components (& strongly & dynamic)
  - Sorting & ordering
  - Colouring
  - Transpose

- Parallel BGL
  - Distributed storage and algorithms
  - Research platform
R - igraph

- Statistics framework
- *igraph*: simple graphs and network analysis
- Graph generation
- Graph manipulation
- Visualization
- Algorithms
  - Shortest path
  - Minimum Spanning Tree
  - Connectivity
  - Structural properties
  - ...

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Visualization softwares

- Graph visualization is a problem on its own
- Lots of R&D efforts in this field
- Some OpenSource tools:
  - Tulip
  - Processing
  - Graphviz
What's best for you – Topology?

Central data repository needed?

Advanced topology model needed?

Network analysis needed?

Y

PostGIS & Own model

PostGIS & NEF model

N

GvSIG

GRASS
What's best for you — Network Analysis

Automation needed?

Y → PostGIS

N → Centralized data?

Y → Good

N → Dev skills / effort?

Y → Huge data?

Y → PBGL

N → Simple

→ Spatialite

OK → NA Complexity?

complex → GRASS

Simple → R

→ BGL

→ GvSIG
Perspectives and issues

- Huge volumes
  - Global earth transportation network
  - Multimodal
  - Time dimension
- Parallel processing
- Live data
  - Near-realtime updates
- Interoperability
  - Conversion tool
  - Smooth integration between GIS and large network analysis tools
That's all folks!

Want to know more?
Ask now or write to:

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