



State of the art of FOSS4G for topology and network analysis

Vincent Picavet

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 complex 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

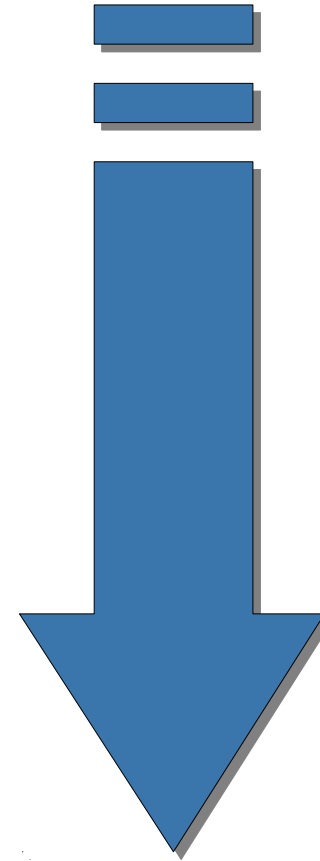


Breakout Session: Spatial Databases
Code Sprint on Friday: PostGIS



Presentation plan

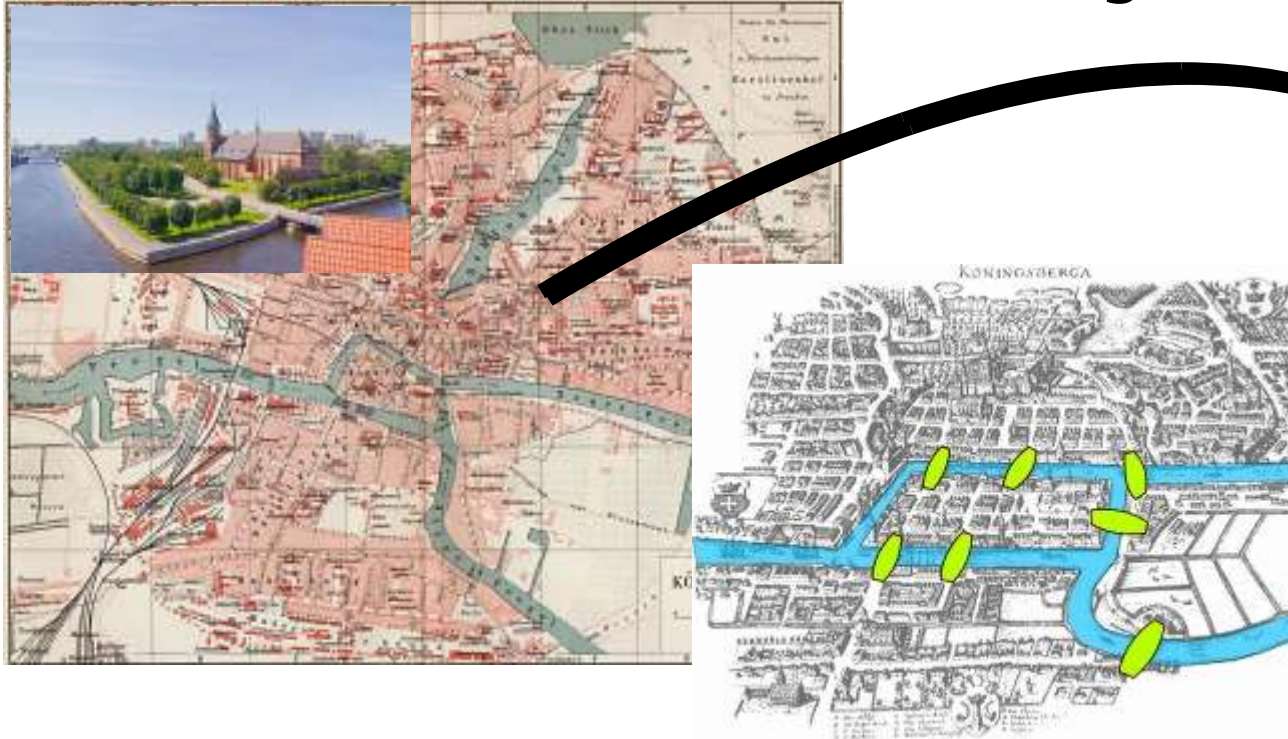
- g Introduction
- g What is topology ?
- g What is Network Analysis ?
- g FOSS4G for topology & NA
- g Conclusion
- g Perspectives
- g Questions



Introduction

Back to the roots

- Problem of the seven bridges of Königsberg



$$e^{i\pi} + 1 = 0$$

- Topology and graph theory was born !

Not so long ago...

- g 4 colors map
 - g «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»
- g Conjecture in 1852 (Francis Guthrie)
- g Proof in 1976
- g First computer-assisted proof
- g **GIS Problems lead to complex theoretical issues**

Nowadays GIS application fields

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



What is topology ?

Topology – General



General :

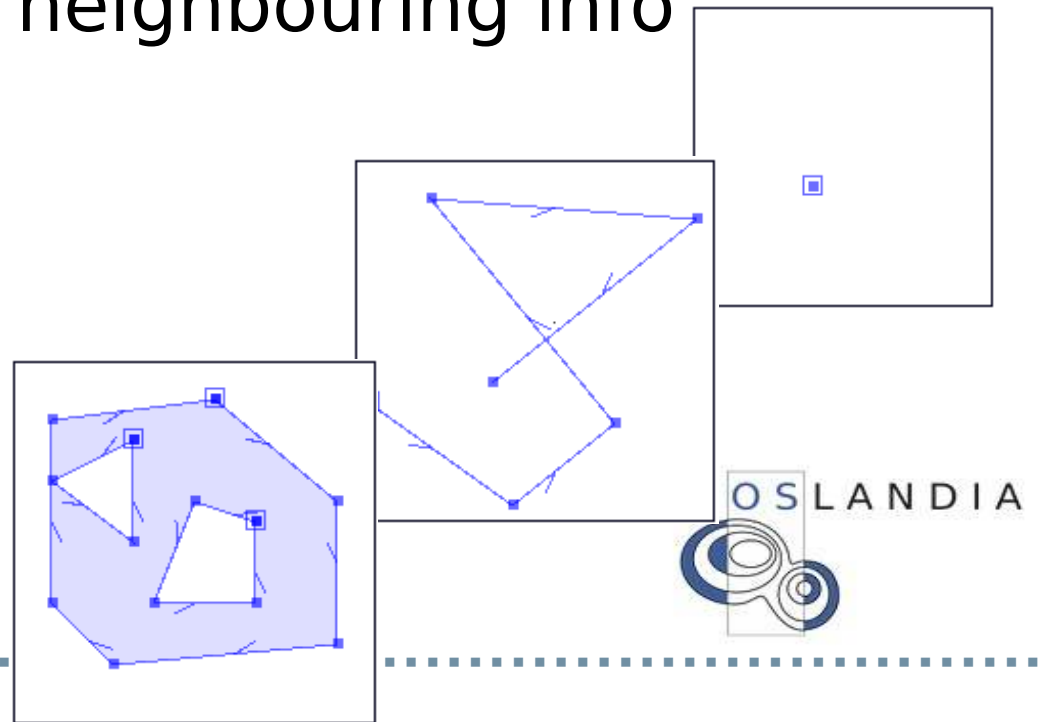
- g «Area of mathematics concerned with spatial properties that are preserved under continuous deformations of objects»

g GIS :

- g «Spatial relationship between geographic features based on location»
- g Implicit on maps : eye-brain system interprets it
- g Needs to be explicit for computer systems
- g Relations
 - g Connectivity, Adjacency, Containment, Proximity, Relative Directions
- g Rules based on relations

Classic feature model

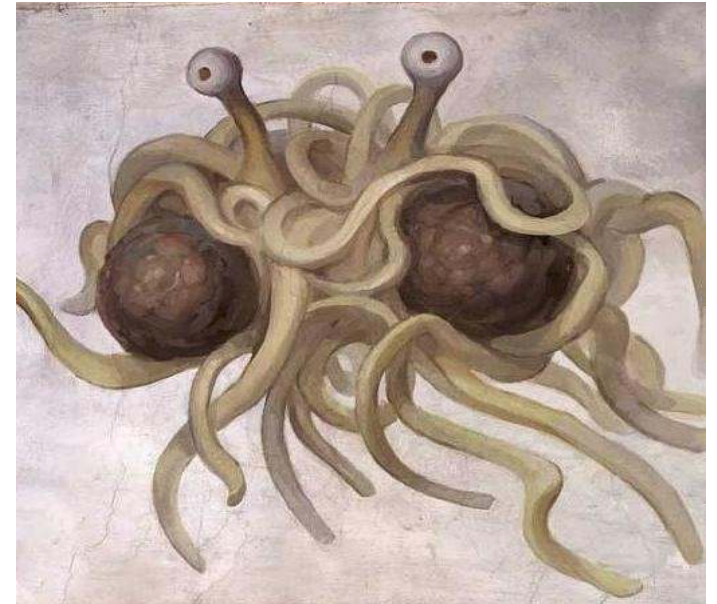
- g aka «Spaghetti model»
- g 1-1 translation of analog map
- g Line = series of ordered (x, y) points
- g Polygon = closed loops define boundaries
- g Different lines/Polygons = independent objects
- g No explicit connectivity & neighbouring info
- g Simple and efficient
 - g Cartographic display
 -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



Why topology ?

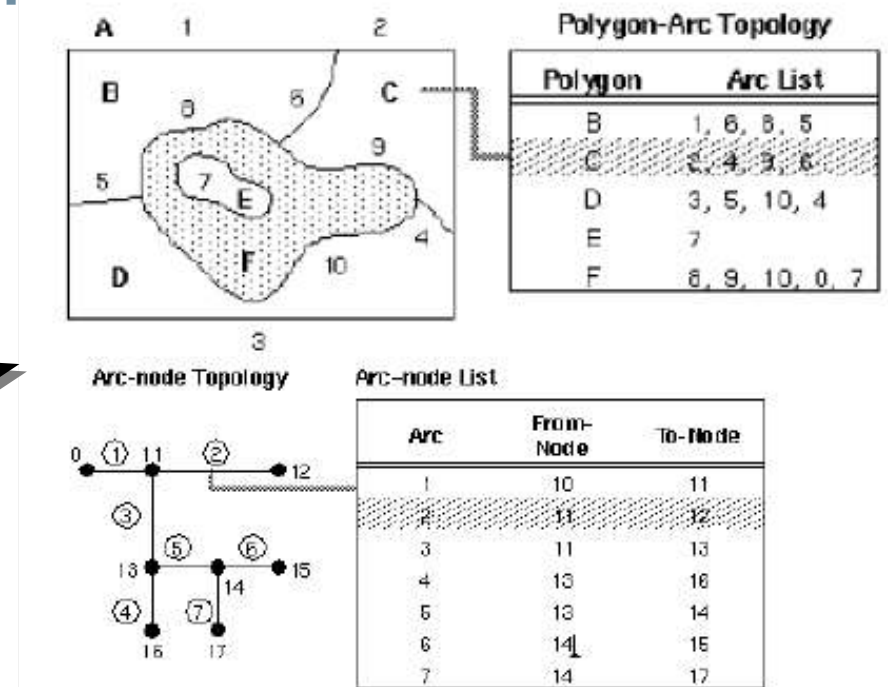
- g Insure correct boundaries
- g Enhance analysis
- g Insure data quality
- g Topological editing and digitizing
- g Needed to do network analysis

Get rid of the Spaghetti Monster !



GIS Formats & topology

- g Your very own topology
 - g Feature-attribute based
 - g Use relations and create rules
- g Classic topology model
 - g Node, arc/edge, face
 - g Connectivity, Direction, Adjacency



- g Most GIS data format → no topology
 - g Except : ArcInfo Coverage, TIGER, DLG, OSM (partly)...

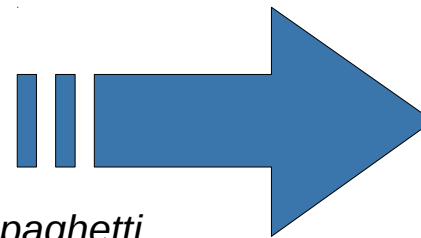
From spaghetti to topological zen

- 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



*Spaghetti
mess*



*Topological
Zen data*

Standardization

- g Main standard, DB-oriented :
 - g BS ISO/IEC 13249-3:2006 aka SQL/MM
- g Defines model and operations
- g Node-edge-face model, with geometry
 - g ST_NODE, ST_EDGE, ST_FACE views
- g ST_CreateTopoGeo, ST_ValidateTopoGeo
- g Editing functions
- g Topology-network model and operations
 - g Creation, validation, editing
 - g Shortest Path

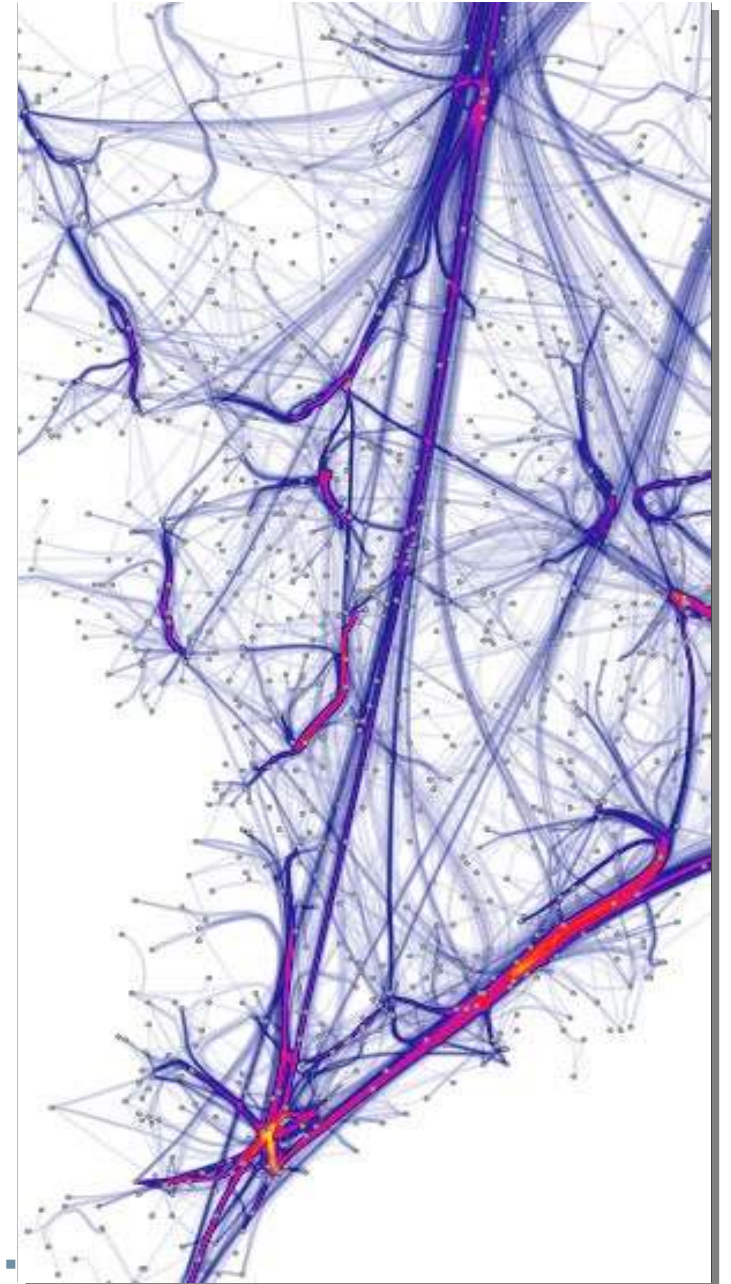
What is Network Analysis ?

Graph Theory – Network theory

- g Graph Theory :
 - g «*Study of graphs: mathematical structures used to model pairwise relations between objects from a certain collection.*»
- g Networks
 - g Nodes & Edges
 - g Directed / Undirected
 - g Weighted or not
 - g Definition varies...
- g Social Networks, Biology, Link analysis, centrality measures...

Some network analysis problems

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



FOSS4G Tools

FOSS4G Softwares

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



PostGIS



- g SQL/MM Topology Model
- g Partial implementation
 - g No network analysis
- g Node-Edge-Face
- g Create, Validate
- g Raw edit
- g 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

- g PostGIS Plugin
- g Own network model
- g Shortest path
- g Driving distances
- g Travelling Salesman Problem
- g Algorithms
 - g Dijkstra
 - g A*
 - g Shooting star (with restrictions)
- g 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);
```



Yokohama (Japan)

Select Routing Method

Shortest Path A Star - undirected

Add START point
 Add FINAL point

Route Reverse Reset

Geocode Address

No data available

Example: 神奈川県横浜市中区海岸通1-2

Geocode Reset

Isoline (Driving Distance)

10000 [m] around START point

Isoline Reset



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...



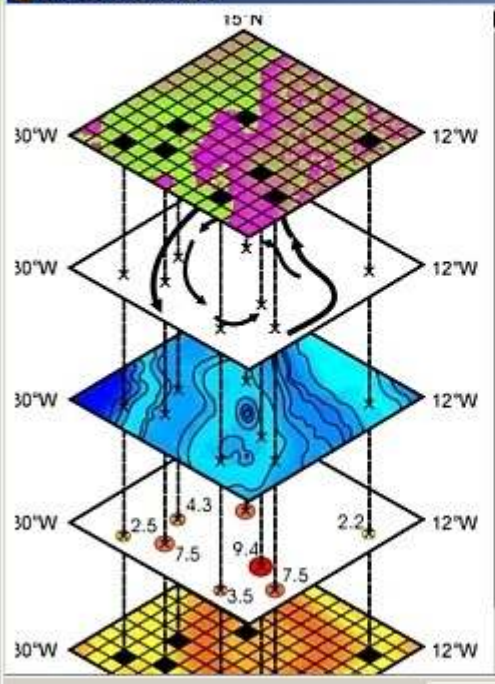
A
 Sistemas_de_Explc
 Default



PluginServices.Procesando
Verificando topología
 Verificando reglapolygon_must_be_closed: 0 de 0

Reglas de la topología.

Reglas.	Capas.
Primera capa que interviene en la regla Infraestructuras_Hidráulicas.shp	
Regla topológica. Las líneas no pueden tener nodos colgantes	
Segunda capa que interviene en la regla Sistemas_de_Explotación.shp	



Reglas de la topología.

Todo extremo de una línea debe tocar a otro extremo de línea o a sí mismo.

Propiedades de la topología.

General | Capas | Reglas | Errores topológicos

Visor de errores topológicos.

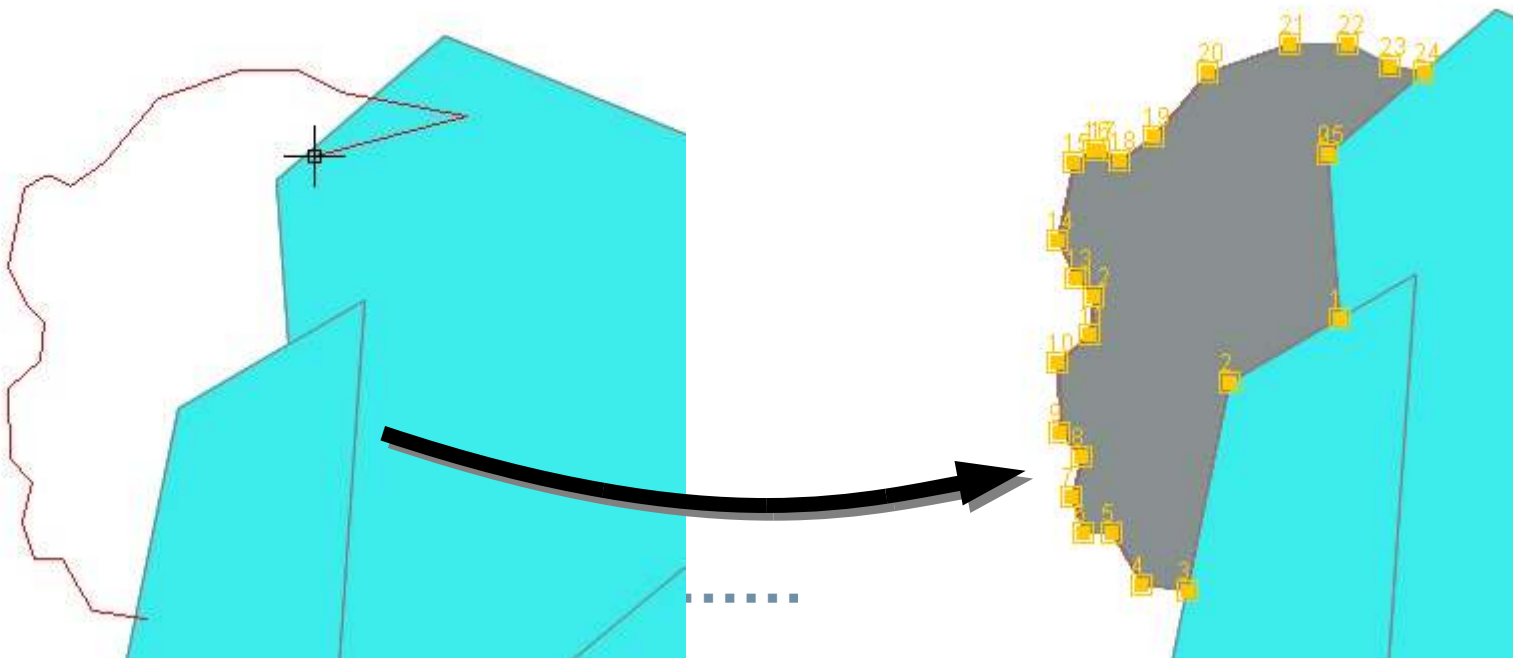
MOSTRAR: Mostrar todas las reglas

Errores Excepciones Solo en vista actual

UPDATE BATCH_FIX

Rule_type	Layer_1	Laye...	Shape_Type	Featur...	Feature_2	Exception
must_not_overlap	Sistemas_de_Explotación.shp		Polígono	0	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	1	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	2	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	3	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	4	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	5	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	6	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	7	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	8	13	No
must_not_overlap	Sistemas_de_Explotación.shp		MULTIGEOMETRY	9	13	No
must_not_overlap	Sistemas_de_Explotación.shp		Polígono	10	13	No
must_not_overlap	Sistemas_de_Explotación.shp		Polígono	11	13	No
must_not_overlap	Sistemas_de_Explotación.shp		Polígono	12	13	No
must not have gaps	Sistemas de Explotación.shp		Polígono			No
			Polígono			No
			Polígono			No
			Polígono			No

Aceptar Cancelar



GvSIG – Network extension

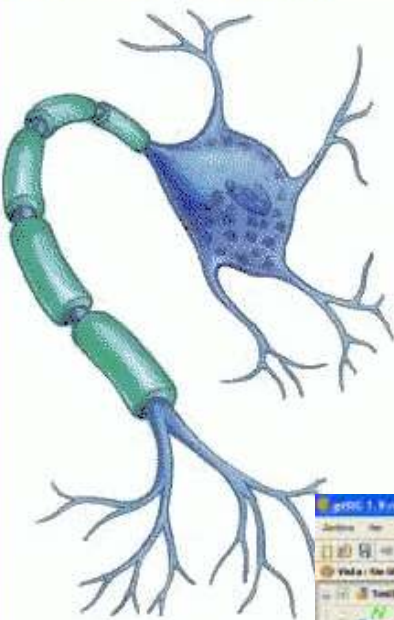
- g Network Analysis
- g Topology builder
 - g Save / reload function (specific format)
- g Interactive GUI for network management
- g Algorithms
 - g Shortest path
 - g Connectivity
 - g Minimal spanning tree
 - g Origin/destination matrix
 - g Finding providers for events
 - g Service zone

GvSIG – Network extension

Red Tabla Shalom Ventana Ayuda

- Generar topología de red
- Cargar topología de red previamente generada
- Cargar red desde fichero...
- Gestión de paradas
- Cargar capa de nodos
- Cargar costes de giro
- Guardar costes de giro
- Camino mínimo
- Area de Servicio
- Evento más cercano
- Matriz Orígenes-Destinos
- Arbol de recubrimiento mínimo
- Conectividad
- Borrar

Generar topología de red...



Configuración de campos

- Seleccione el campo de tipo de vía.: TIPORED
- Seleccione el campo de longitud (metros): LENGTH
- campo de coste: COST
- factor de conversión: 1.00
- Seleccione el campo de sentido: SEN

Sentido de digitalización: 1

Inverso al digitalizado: 2

Guardar fichero de topología en: []

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](#)

17. Llegada a: **MERCEDES**

Distancia acumulada:0,07

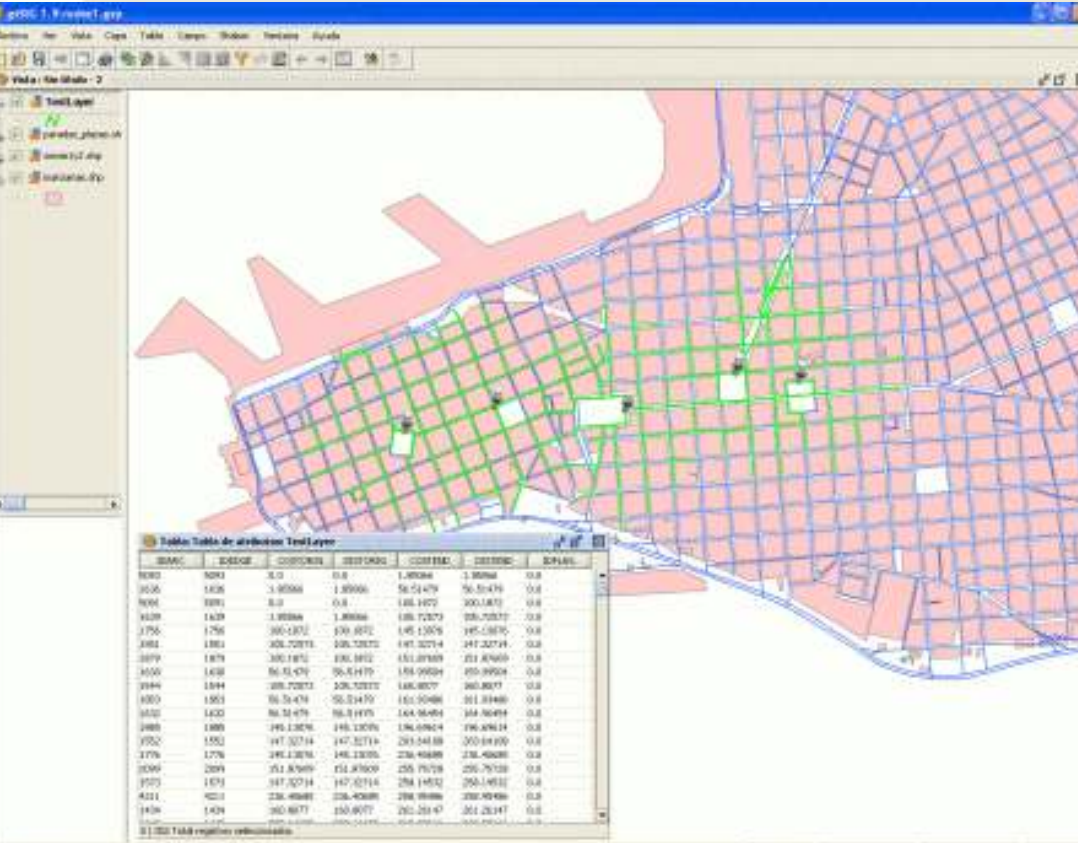
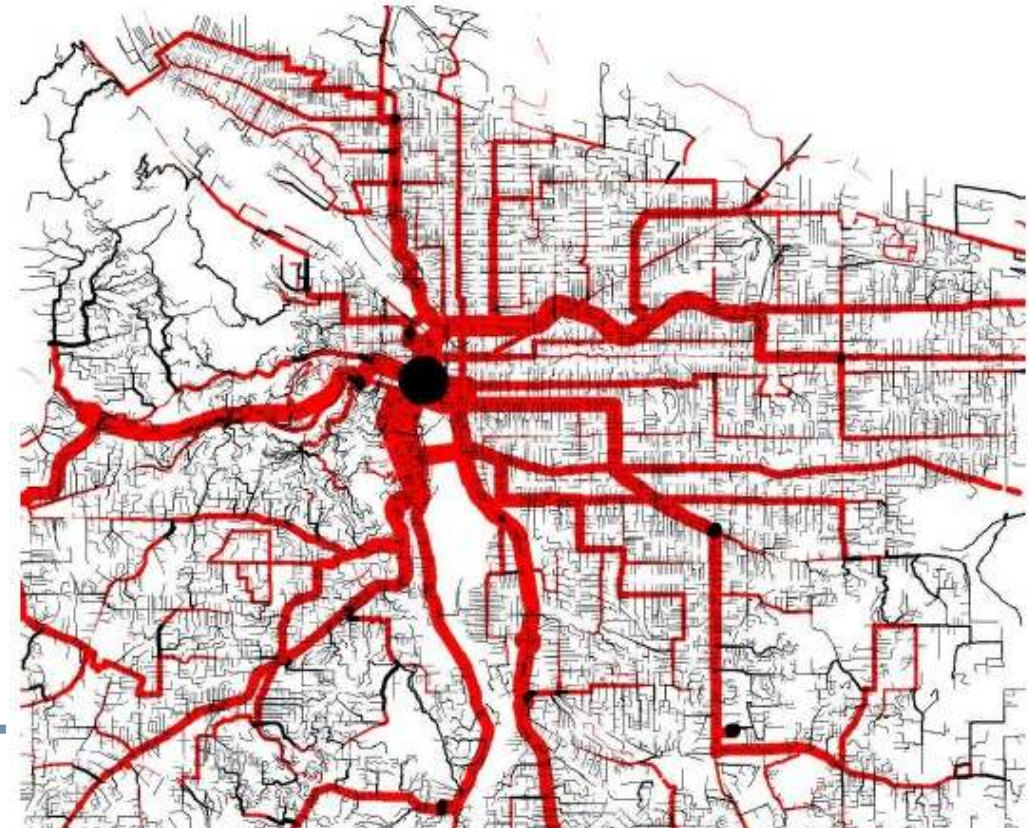


Tabla Tabla de atribuciones TestLayer

ID	LONG	COSTO	TIPORED	SEN	SEN2
1000	1000	0,0	0,0	1,0000	1,0000
1001	1001	1,0000	1,0000	50,0000	50,0000
1002	1002	0,0	0,0	100,0000	100,0000
1003	1003	1,0000	1,0000	100,0000	100,0000
1004	1004	100,0000	100,0000	100,0000	100,0000
1005	1005	100,0000	100,0000	100,0000	100,0000
1006	1006	100,0000	100,0000	100,0000	100,0000
1007	1007	100,0000	100,0000	100,0000	100,0000
1008	1008	100,0000	100,0000	100,0000	100,0000
1009	1009	100,0000	100,0000	100,0000	100,0000
1010	1010	100,0000	100,0000	100,0000	100,0000
1011	1011	100,0000	100,0000	100,0000	100,0000
1012	1012	100,0000	100,0000	100,0000	100,0000
1013	1013	100,0000	100,0000	100,0000	100,0000
1014	1014	100,0000	100,0000	100,0000	100,0000
1015	1015	100,0000	100,0000	100,0000	100,0000
1016	1016	100,0000	100,0000	100,0000	100,0000
1017	1017	100,0000	100,0000	100,0000	100,0000
1018	1018	100,0000	100,0000	100,0000	100,0000
1019	1019	100,0000	100,0000	100,0000	100,0000
1020	1020	100,0000	100,0000	100,0000	100,0000
1021	1021	100,0000	100,0000	100,0000	100,0000
1022	1022	100,0000	100,0000	100,0000	100,0000
1023	1023	100,0000	100,0000	100,0000	100,0000
1024	1024	100,0000	100,0000	100,0000	100,0000
1025	1025	100,0000	100,0000	100,0000	100,0000
1026	1026	100,0000	100,0000	100,0000	100,0000
1027	1027	100,0000	100,0000	100,0000	100,0000
1028	1028	100,0000	100,0000	100,0000	100,0000
1029	1029	100,0000	100,0000	100,0000	100,0000
1030	1030	100,0000	100,0000	100,0000	100,0000
1031	1031	100,0000	100,0000	100,0000	100,0000
1032	1032	100,0000	100,0000	100,0000	100,0000
1033	1033	100,0000	100,0000	100,0000	100,0000
1034	1034	100,0000	100,0000	100,0000	100,0000
1035	1035	100,0000	100,0000	100,0000	100,0000
1036	1036	100,0000	100,0000	100,0000	100,0000
1037	1037	100,0000	100,0000	100,0000	100,0000
1038	1038	100,0000	100,0000	100,0000	100,0000
1039	1039	100,0000	100,0000	100,0000	100,0000
1040	1040	100,0000	100,0000	100,0000	100,0000
1041	1041	100,0000	100,0000	100,0000	100,0000
1042	1042	100,0000	100,0000	100,0000	100,0000
1043	1043	100,0000	100,0000	100,0000	100,0000
1044	1044	100,0000	100,0000	100,0000	100,0000
1045	1045	100,0000	100,0000	100,0000	100,0000
1046	1046	100,0000	100,0000	100,0000	100,0000
1047	1047	100,0000	100,0000	100,0000	100,0000
1048	1048	100,0000	100,0000	100,0000	100,0000
1049	1049	100,0000	100,0000	100,0000	100,0000
1050	1050	100,0000	100,0000	100,0000	100,0000
1051	1051	100,0000	100,0000	100,0000	100,0000
1052	1052	100,0000	100,0000	100,0000	100,0000
1053	1053	100,0000	100,0000	100,0000	100,0000
1054	1054	100,0000	100,0000	100,0000	100,0000
1055	1055	100,0000	100,0000	100,0000	100,0000
1056	1056	100,0000	100,0000	100,0000	100,0000
1057	1057	100,0000	100,0000	100,0000	100,0000
1058	1058	100,0000	100,0000	100,0000	100,0000
1059	1059	100,0000	100,0000	100,0000	100,0000
1060	1060	100,0000	100,0000	100,0000	100,0000
1061	1061	100,0000	100,0000	100,0000	100,0000
1062	1062	100,0000	100,0000	100,0000	100,0000
1063	1063	100,0000	100,0000	100,0000	100,0000
1064	1064	100,0000	100,0000	100,0000	100,0000
1065	1065	100,0000	100,0000	100,0000	100,0000
1066	1066	100,0000	100,0000	100,0000	100,0000
1067	1067	100,0000	100,0000	100,0000	100,0000
1068	1068	100,0000	100,0000	100,0000	100,0000
1069	1069	100,0000	100,0000	100,0000	100,0000
1070	1070	100,0000	100,0000	100,0000	100,0000
1071	1071	100,0000	100,0000	100,0000	100,0000
1072	1072	100,0000	100,0000	100,0000	100,0000
1073	1073	100,0000	100,0000	100,0000	100,0000
1074	1074	100,0000	100,0000	100,0000	100,0000
1075	1075	100,0000	100,0000	100,0000	100,0000
1076	1076	100,0000	100,0000	100,0000	100,0000
1077	1077	100,0000	100,0000	100,0000	100,0000
1078	1078	100,0000	100,0000	100,0000	100,0000
1079	1079	100,0000	100,0000	100,0000	100,0000
1080	1080	100,0000	100,0000	100,0000	100,0000
1081	1081	100,0000	100,0000	100,0000	100,0000
1082	1082	100,0000	100,0000	100,0000	100,0000
1083	1083	100,0000	100,0000	100,0000	100,0000
1084	1084	100,0000	100,0000	100,0000	100,0000
1085	1085	100,0000	100,0000	100,0000	100,0000
1086	1086	100,0000	100,0000	100,0000	100,0000
1087	1087	100,0000	100,0000	100,0000	100,0000
1088	1088	100,0000	100,0000	100,0000	100,0000
1089	1089	100,0000	100,0000	100,0000	100,0000
1090	1090	100,0000	100,0000	100,0000	100,0000
1091	1091	100,0000	100,0000	100,0000	100,0000
1092	1092	100,0000	100,0000	100,0000	100,0000
1093	1093	100,0000	100,0000	100,0000	100,0000
1094	1094	100,0000	100,0000	100,0000	100,0000
1095	1095	100,0000	100,0000	100,0000	100,0000
1096	1096	100,0000	100,0000	100,0000	100,0000
1097	1097	100,0000	100,0000	100,0000	100,0000
1098	1098	100,0000	100,0000	100,0000	100,0000
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1100	1100	100,0000	100,0000	100,0000	100,0000

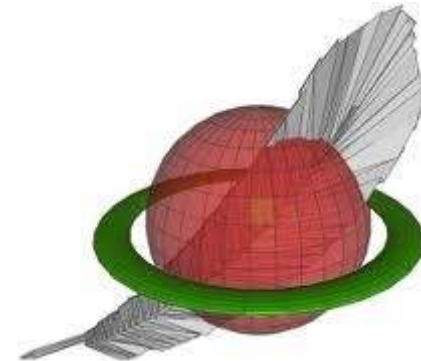
GraphServer

- 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

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



Build Network

Base Table [graph]

- geometry_columns
- geometry_columns_auth
- layer_params
- layer_statistics
- layer_sub_classes
- layer_table_layout
- pattern_bitmaps
- project_defs
- router_parameters
- roads**
- spatial_ref_sys
- style_sequence
- symbol_bitmaps
- views_geometry_columns
- verts_geometry_columns

Network configuration

NodeFrom Column: osm_id, class, **node_from**, node_to, name

NodeTo Column: class, **node_from**, **node_to**, name, osm_id, osm_type

Geometry Column: oneway, tofrom, length, **cost**, geometry

Arc connections: Uni-Directional, Bi-Directional

Cost type: Using Length as Cost, Using Cost Column

Cost Column: oneway, tofrom, oneway_tofrom, length, **cost**, geometry

OneWay Columns: Enable OneWays

From -> To: node_to, name, **oneway_fromto**, oneway_tofrom, length

To -> From: node_to, name, **oneway_fromto**, oneway_tofrom, length

Name Column: Enable Name

node_from, node_to, name, **oneway_fromto**, osm_id, osm_type

OK Cancel

Files

CT:\sviluppo\proj-epsq\luxamb
roads.geometry

Navigation
Current Draw Mode
Identify
Editing disabled
Set Route Start
Set Route End
Return Trip
Route Clear

49°34'37"N 6°06'46"E

Routing Solution

Connection

NodeFrom: 70825205 TotalCost: 1002.395303 Elapsed Time: 00:00:406

NodeTo: 255876666 RouteLength: 22443.05 m

Routing Details

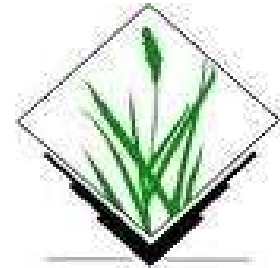
	ArcRowid	NodeFrom	NodeTo	ArcCost	TotalCost	
48	2885	262391898	291723849	3.12	252.51	N 51
49	2884	291723849	278517953	0.89	253.40	N 51
50	2883	278517953	141644	1.12	254.52	N 51
51	2882	141644	278517948	2.82	257.34	N 51
52	2881	278517948	141637	6.94	264.28	N 51
53	14767	141637	291089934	10.30	274.57	Route d'Arion
54	14766	291089934	252019709	1.17	275.74	Route d'Arion
55	4784	252019709	291089939	1.34	277.08	Route d'Arion

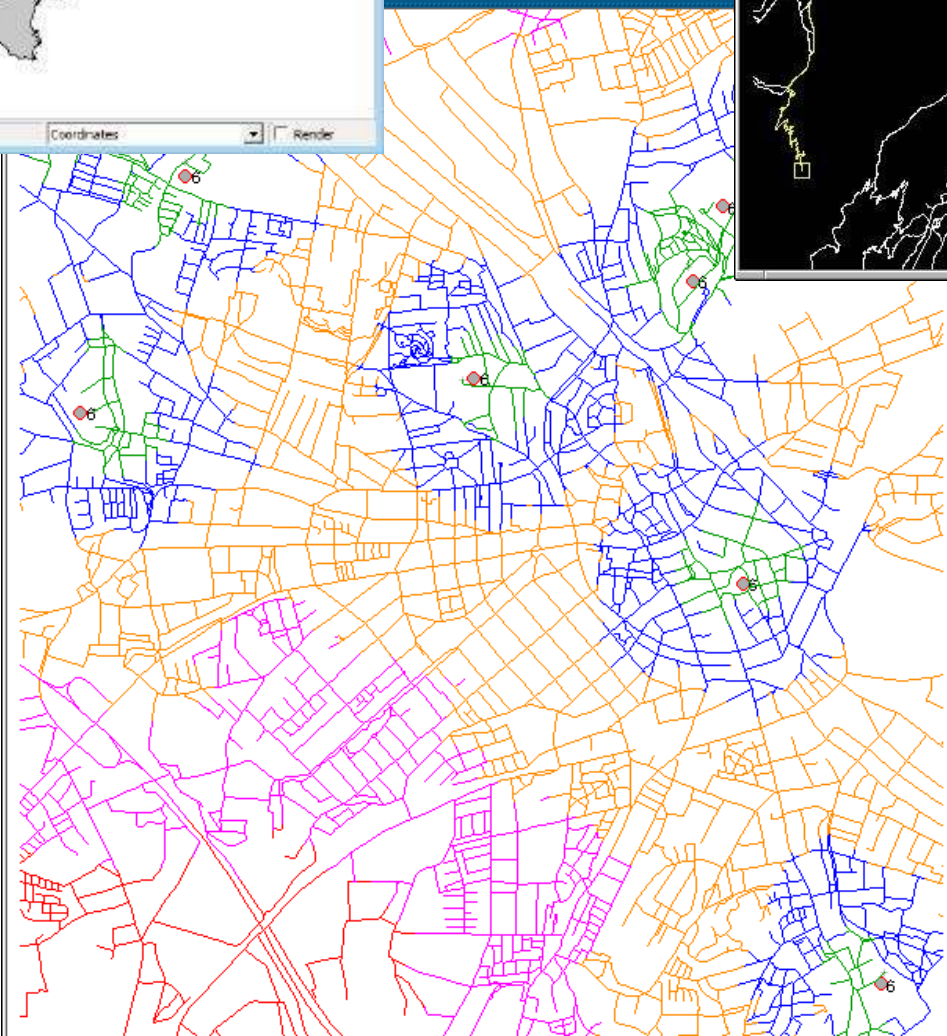
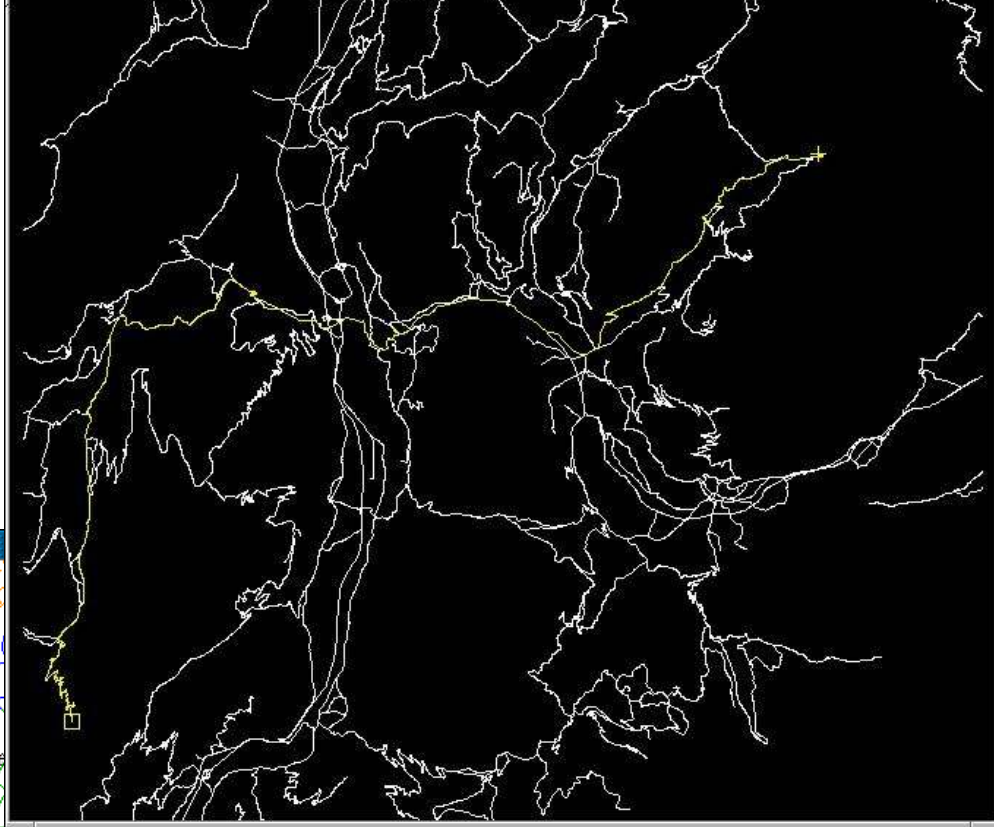
Close



GRASS

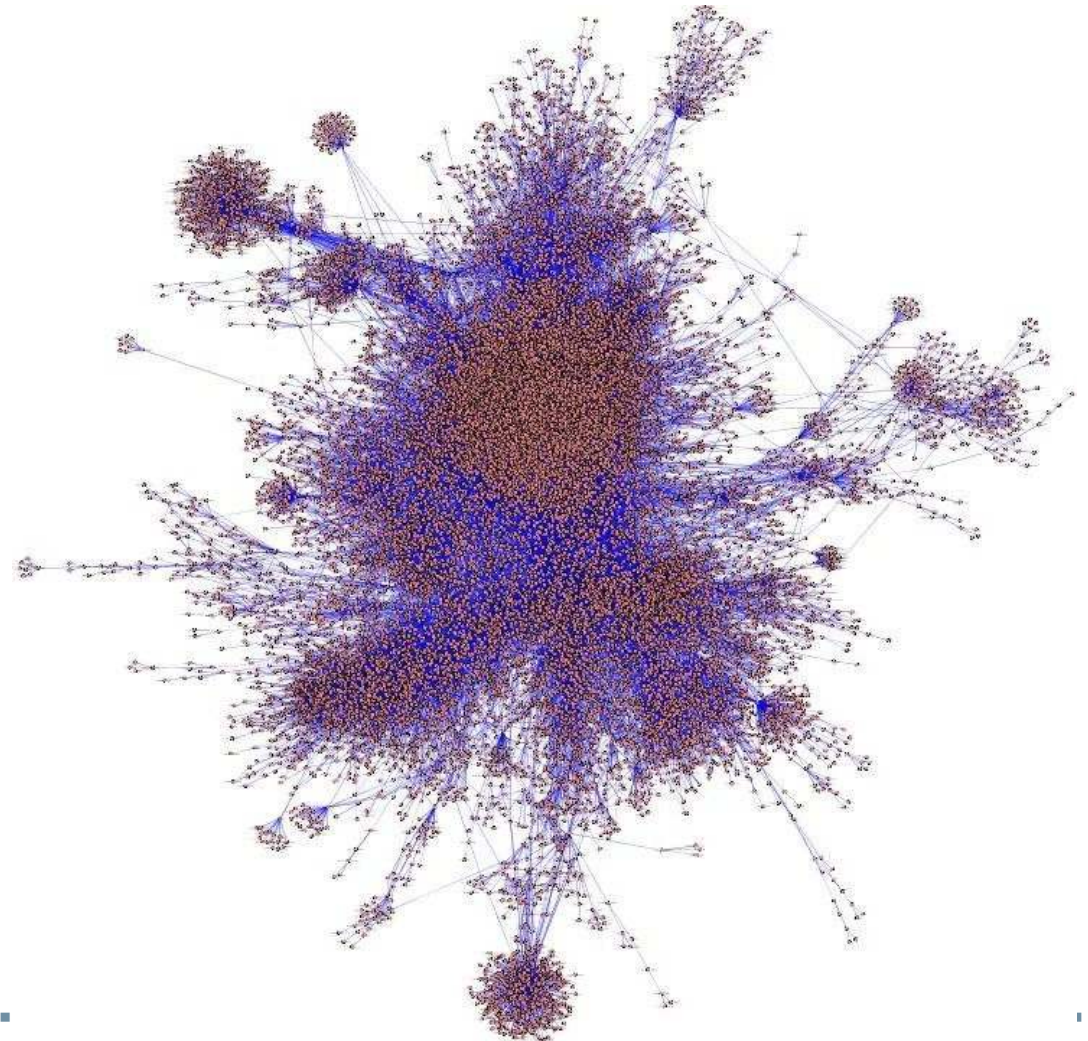
- Native N-E-F topology
 - Built automatically
 - Supports digitizing
 - Cleaning module & network maintenance (*v.clean*, *v.net*)
- Graph & network analysis modules
 - Through DGLib (Directed Graph Library)
 - Algorithms
 - Shortest path (*v.net.path*, *d.path*, *v.net.timtable*)
 - TSP (*v.net.salesman*)
 - 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

- g Boost Graph Library

- g «standard» C++ library
- g High quality & highly customizable
- g Efficient algorithms



- g Implements

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

- g Parallel BGL

- g Distributed storage and algorithms



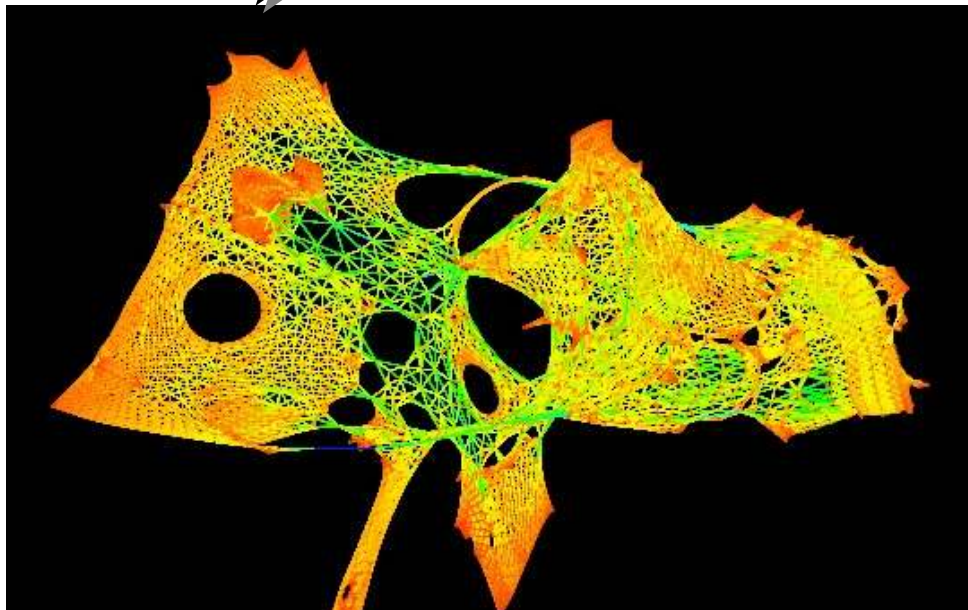
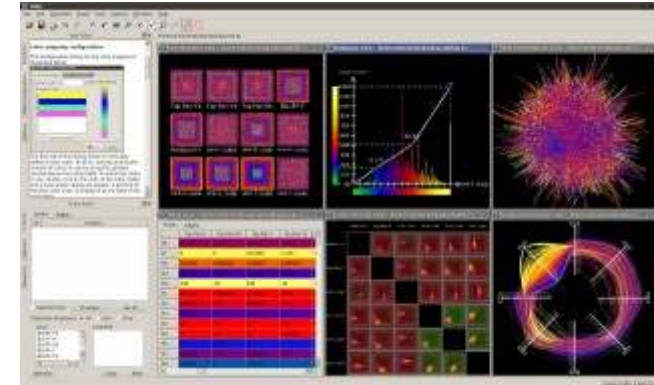
- g Research platform

R - igraph

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

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 ?

What's best for you – Network Analysis

Perspectives and issues

- g Huge volumes
 - g Global earth transportation network
 - g Multimodal
 - g Time dimension
- g Parallel processing
- g Live data
 - g Near-realtime updates
- g Interoperability
 - g Conversion tool
 - g 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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