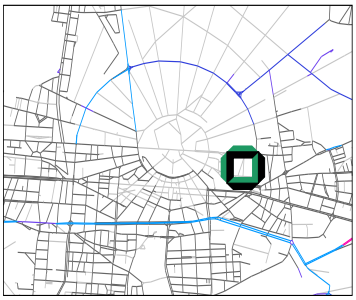
Study Thesis
Visualisation of Very Large Graphs

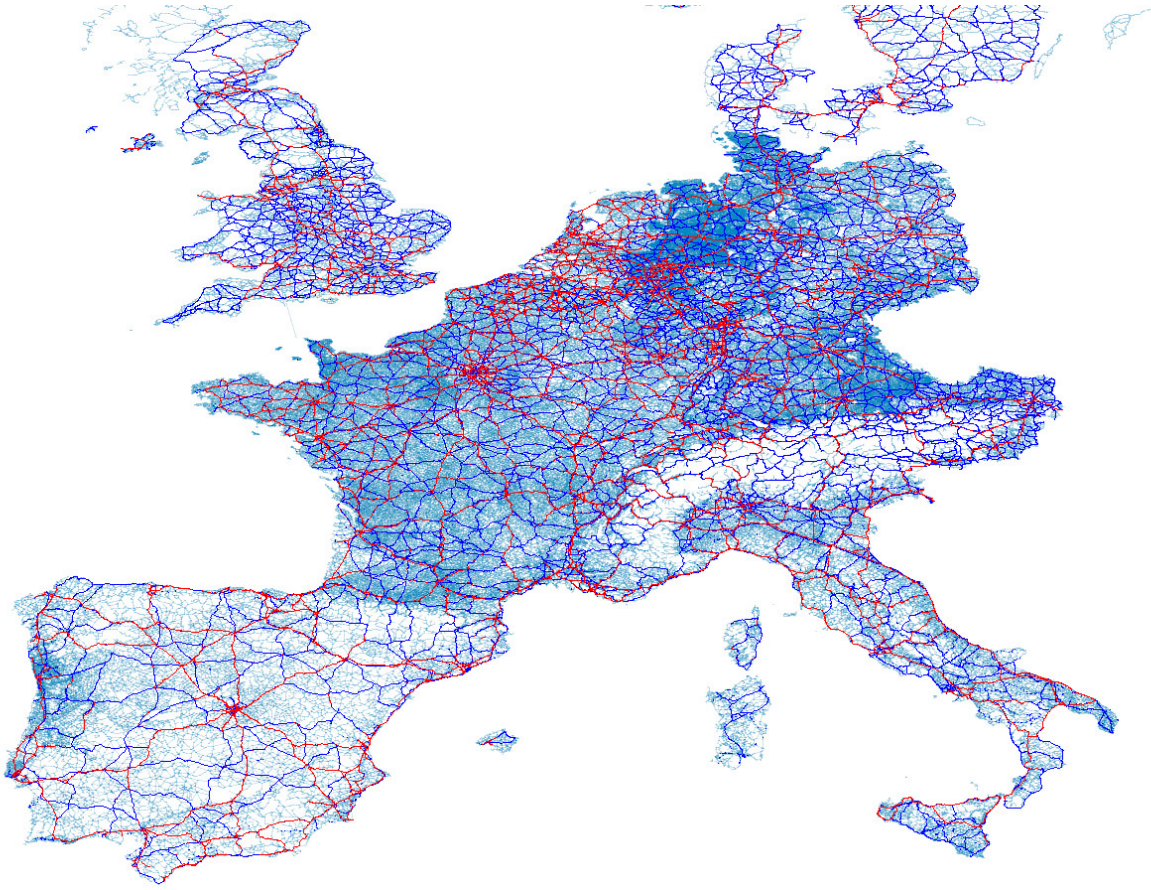


Timo Bingmann

Aug 2, 2006

Road Map

Motivation



Motivation

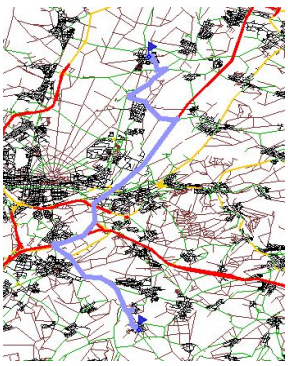
Visualisation of a street network of Europe.

Magnitudes

- About 18 million vertices and 22 million edges.
- Last picture: only about 3 million edges.

Application

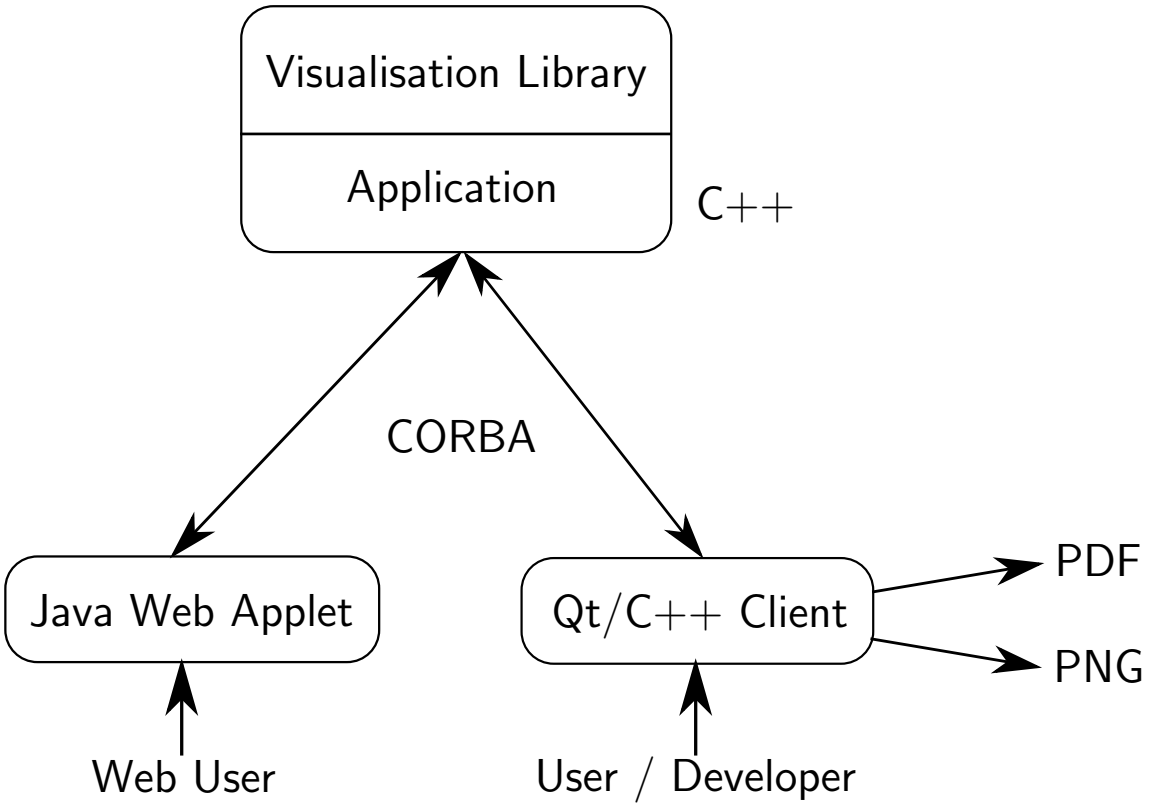
- Route planning
  $\Rightarrow$ drawing of paths.



Visualisation Library

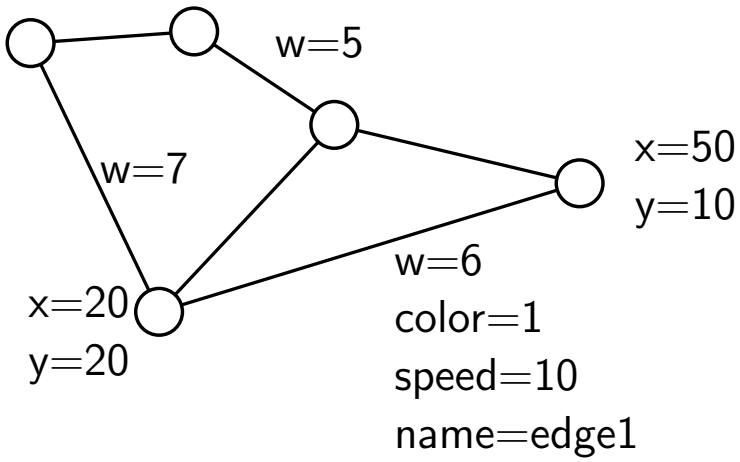
- Supports any two dimensional layouted graph.
- Very fast query speeds: < 1 sec.
- Seamless integration into existing applications.
- Easily animate calculation mechanisms of algorithms.
- Fast and user-friendly browsing at presentations or via the Internet.
  $\Rightarrow$ Java web applet.
- High-quality exports of sections to PDF or PNG for presentations and papers.

Basic Architecture



Supported Graphs

- Two dimensional layouted graph
- An additional z-axis (significance)
- Attributes on vertices and edges: coordinates and drawing parameters.
- Each attribute has a type like `bool`, `char`, `integer` or `string`.

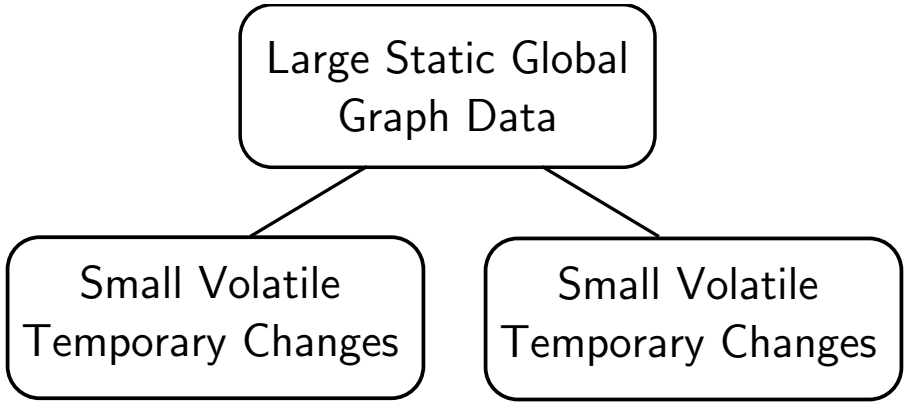


Analysis: Route Planning

The route planning algorithm operates on a street network.

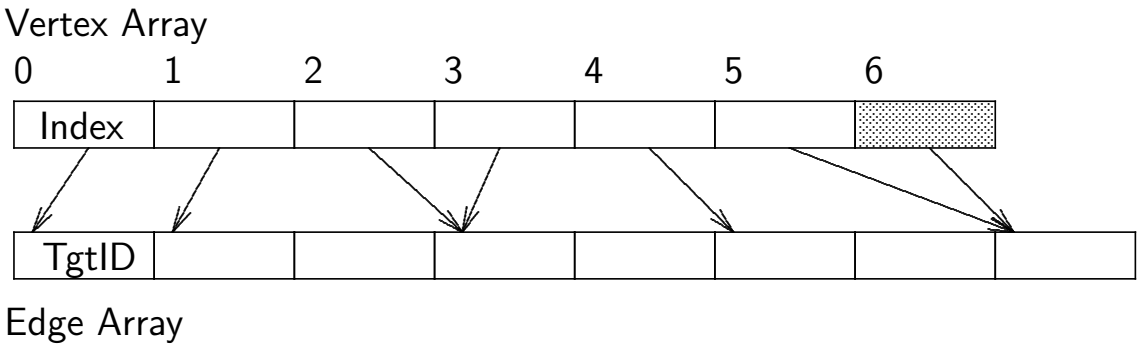
- Large volume of unchanging graph data. Route planning never changes streets.
- Only small set of edges are marked by the algorithm.
- Marked edges are undone after viewing.
- $\Rightarrow$ Separate static graph data from temporary changes.

Separation



- Temporary changes are an overlay graph.
  $\Rightarrow$ efficient rollback of changes.
- Can apply compact data structures to static graph data. $\Rightarrow$ adjacency array
- Support of multiple simultaneous clients.
  $\Rightarrow$ multi-threading support.

Adjacency Array



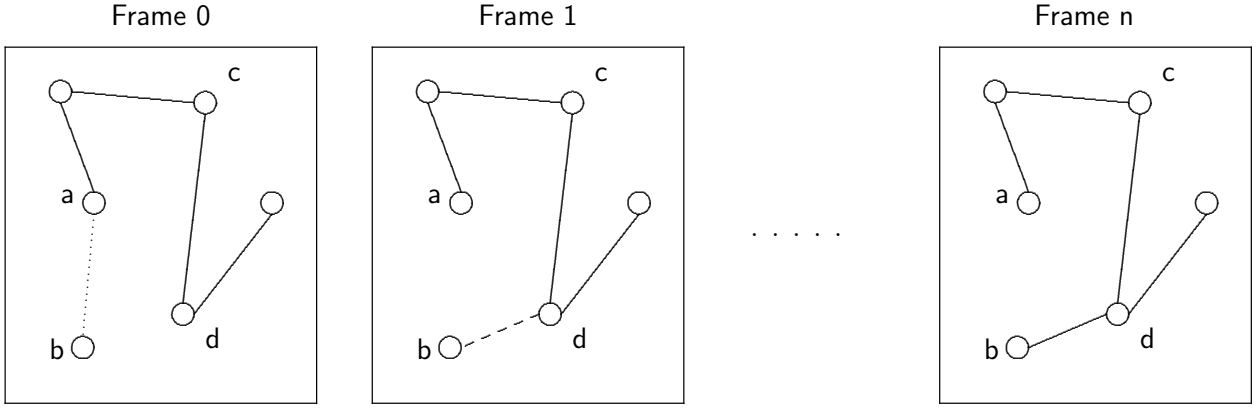
- Compact and easy to serialize.
- Array has to be rebuilt to apply changes.
- Attribute values are stored in a similar fashion.
- `GraphLoader` class for direct loading of arrays.

Changelist

- Save temporary changes in flexible `hash_map` structures.
- Support convenient functions to change graph data:
  - `addVertex(vid)`
  - `setVertexAttr(vid, attrid, value)`
  - `delVertex(vid)`
  - `addEdge(src, tgt)`
  - `setEdgeAttr(src, tgt, attrid, value)`
  - `delEdge(src, tgt)`

Animation Timeline

- Changes can be animated by setting time frame markers in the sequence of function calls.



Index Structure

Required

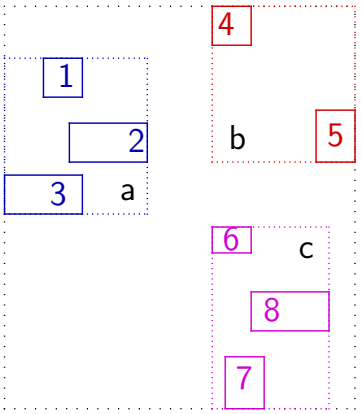
Spatial index structure to accelerate range queries on the graph. Needs to support zooming and extraction in z-order.

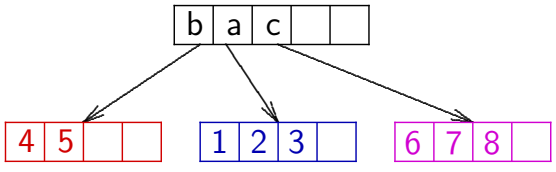
Selected

R-Tree

R-Tree

- Based on B-Tree, but contains rectangles instead of numbers.
- Efficient for very large number of rectangles through high fan-out.

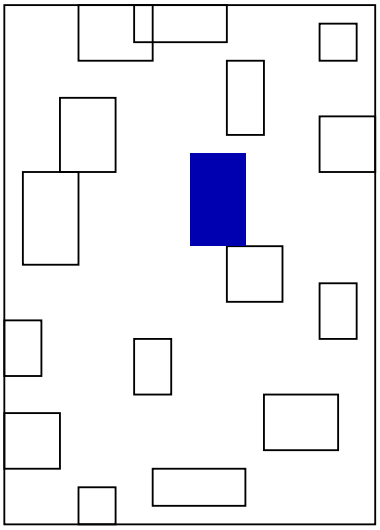




R-Tree Properties

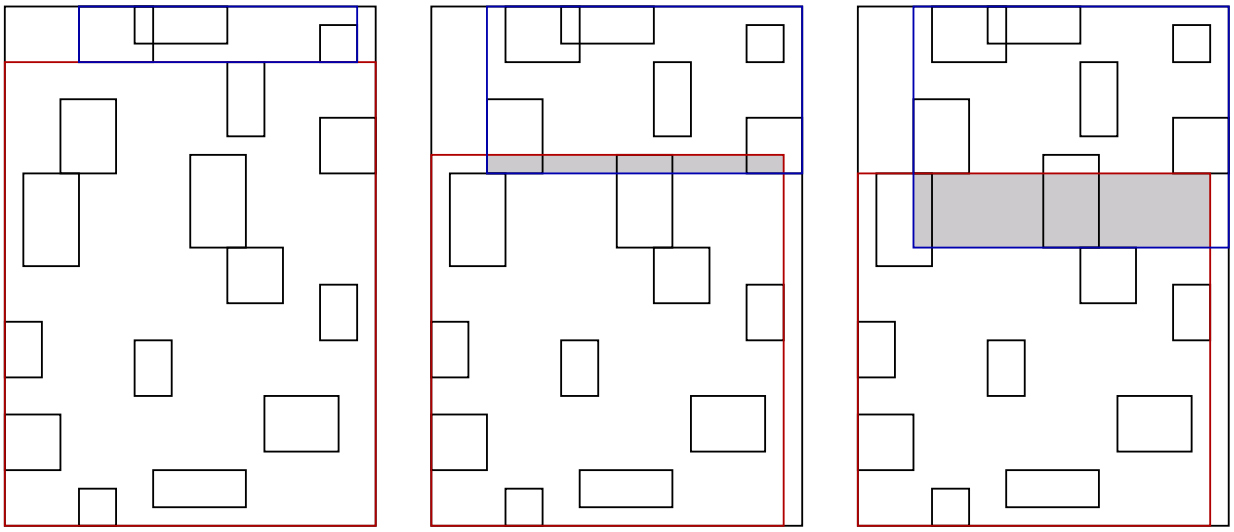
- Define M maximum and m minimum number of rectangles in a node. Let $m \leq \frac{M}{2}$.
- Every node contains between m and M rectangles or it is the root.
- The root contains at least two rectangles or it is a leaf.
- Every rectangle in an inner node is the minimum bounding-box of the rectangles contained in its subtree.
- All leaves are on the same level.

R-Tree Splitting

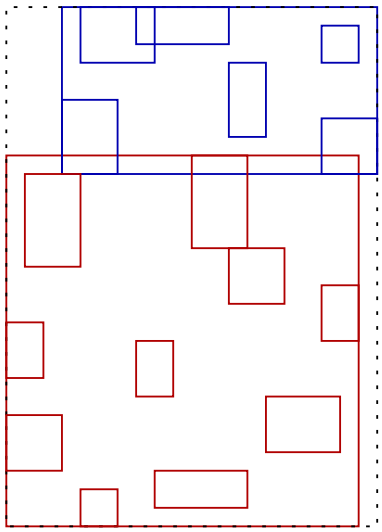


- How to find a good split when a node overflows?

R-Tree Splitting

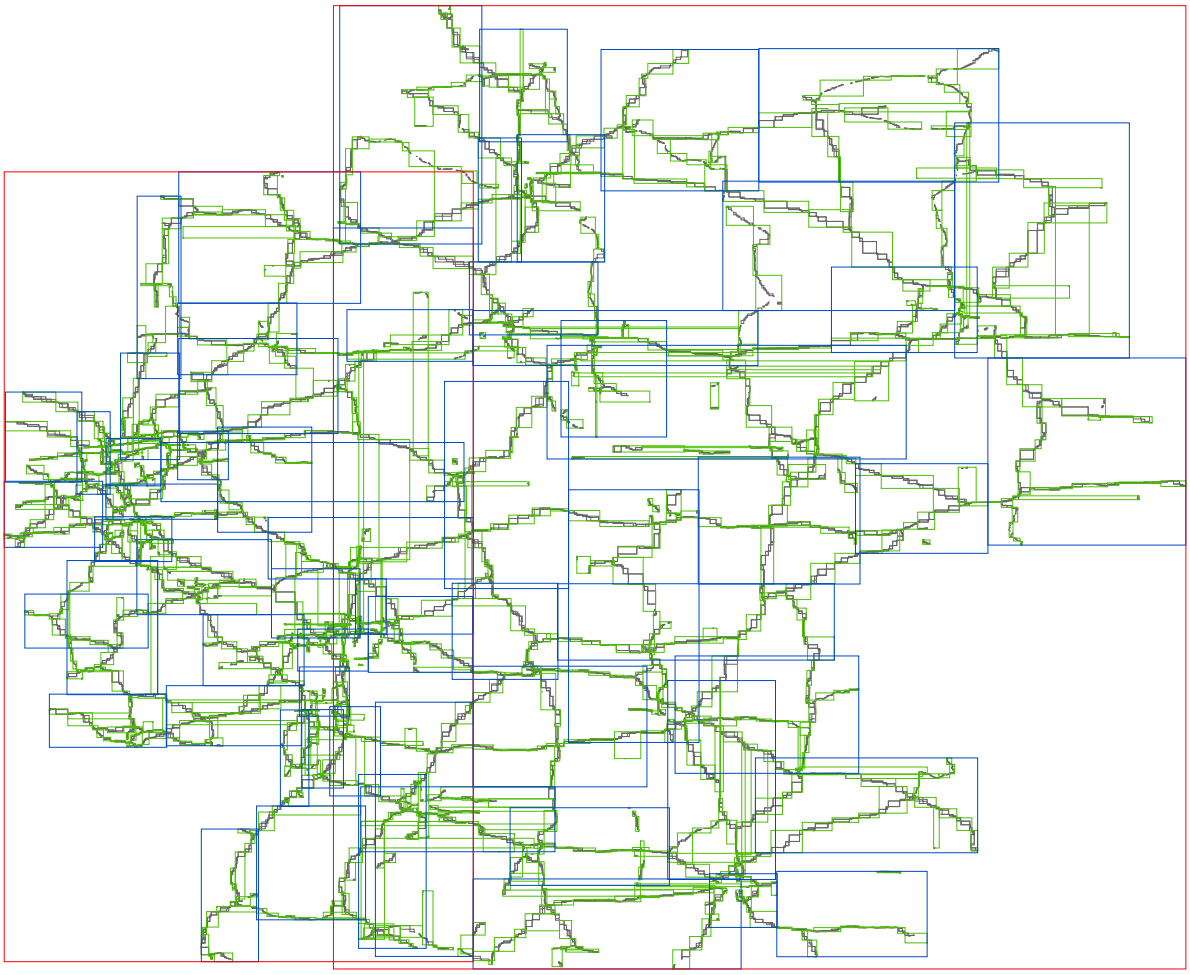


R-Tree Splitting



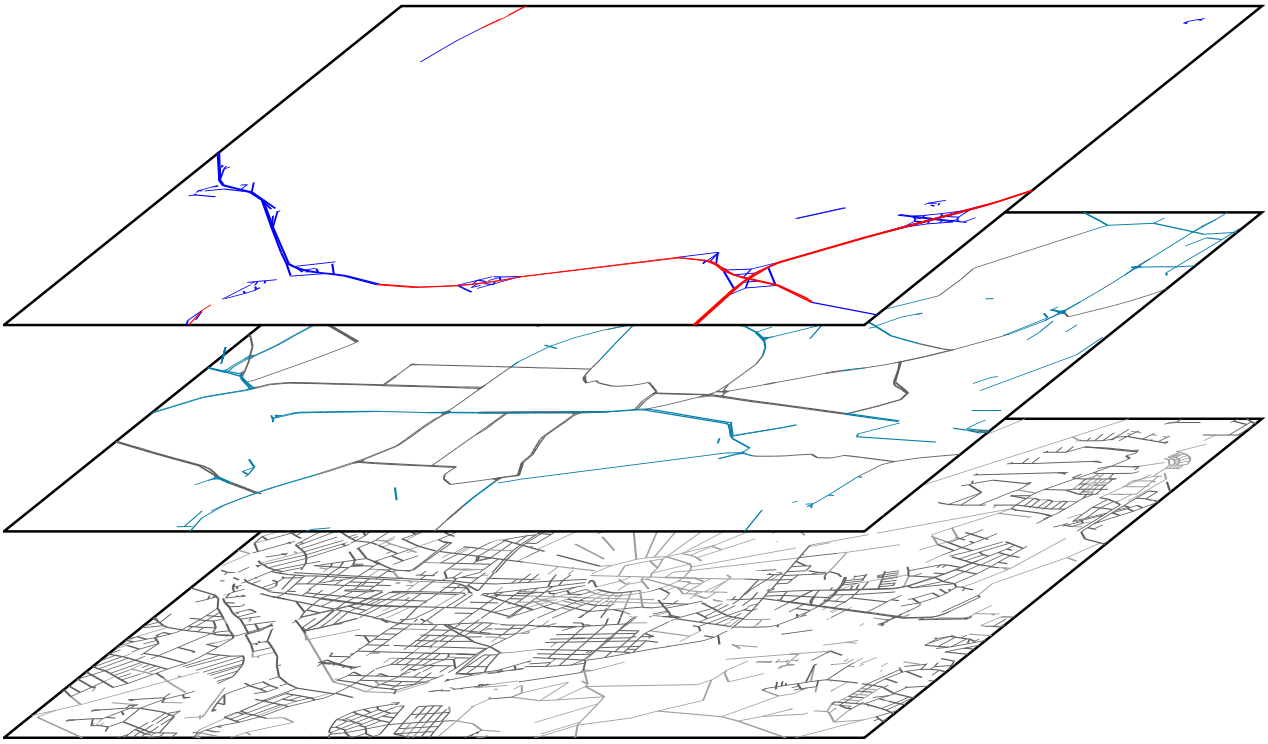
- Library contains three R-tree Variants: R-Tree with quadratic Split, R-Tree with linear Split and R*-Tree.

Germany's Autobahnen



Multilevel R-Tree

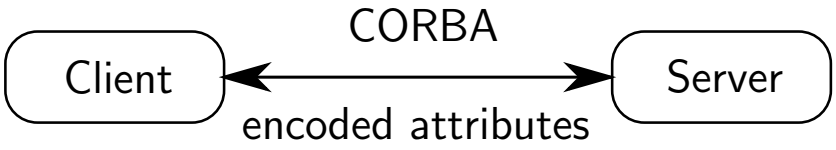
Multiple R-Trees are used to support extraction in z-order.



getArea Query

- Vertices and edges are extracted and sent to the client in a serialized binary format.
- Change function calls are sent as an animation script.
- Visualisation library is not limited to CORBA as middleware.

getArea Query



- Send only attributes required to draw the graph.
- Screen coordinate transformation is calculated on the server. Transfered as `short`.
- User can set a filter to limit the drawn edges.

Parser

Server contains an arithmetic parser used to parse

- attribute selection strings

```
(x - 5411) * 0.331 cast short, ..., speed
```

- and user filter strings.

```
edges:  (speed < 5 and distance > 50) or (speed >= 5)
```

id	1	2	3	4	5	6
x	5641	5560	5755	5708	5638	5236
y	4845	4853	5002	4905	4998	4821
speed	5	6	1	3	4	2
distance	42	12	6	66	36	22
(x-5411)*0.331	76	49	113	98	75	−57

Integration

Easy integration into existing programs.

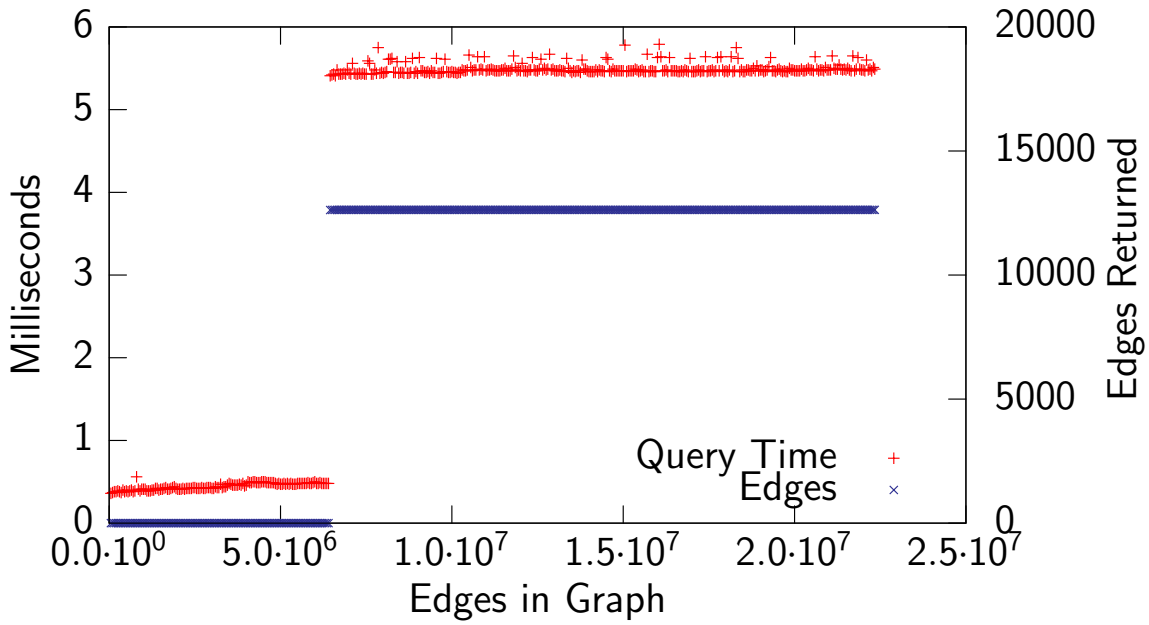
- Well-designed C++ namespace with lots of doxygen documentation.
- Animation is automatically created from sequence of function calls.
- Accelerated loading from snapshot data files containing the complete server state.

Map Sizes

Map	Vertices Edges	Base Graph Attributes	R-Trees Total
Luxembourg	30 747	538 KB	517 KB
	38 143	531 KB	1586 KB
Belgium	463 795	8 269 KB	7 895 KB
	594 715	8 142 KB	24 307 KB
Netherlands	893 407	15 920 KB	15 174 KB
	1 144 337	15 675 KB	46 769 KB
Germany	4 378 447	77 210 KB	73 643 KB
	5 504 454	76 111 KB	226 964 KB
Europe	18 029 722	315 385 KB	301 322 KB
	22 339 557	311 176 KB	927 883 KB

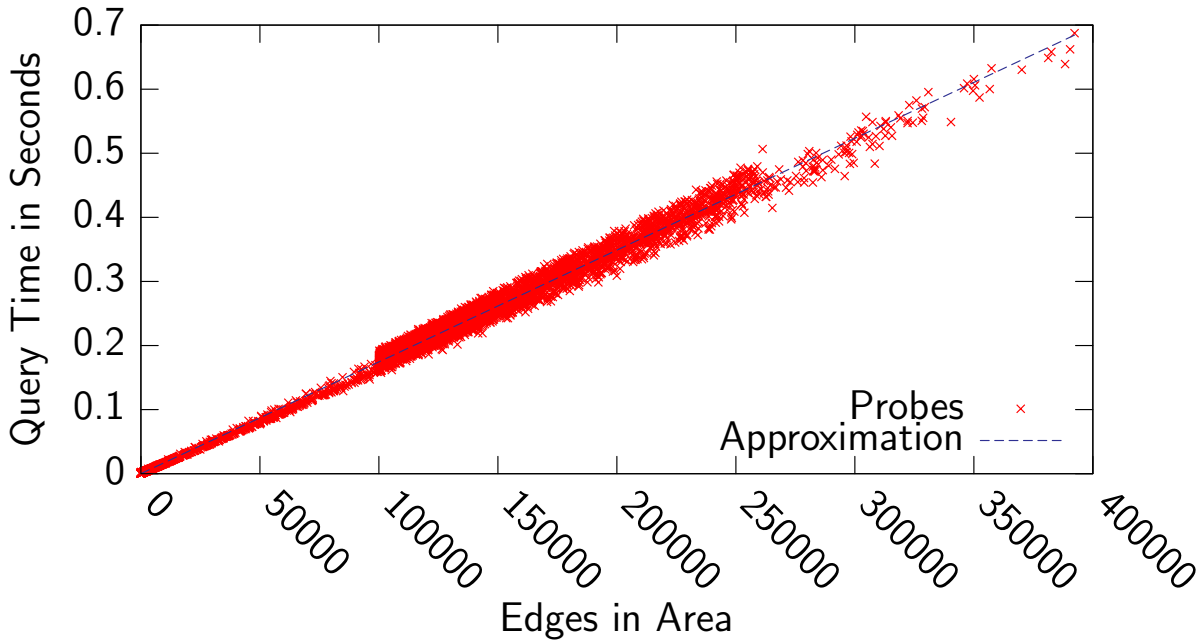
Table: Map Sizes

Query Speed



- Street network of Europe built incrementally.
- Query time measured on a fixed view of Karlsruhe with surrounding cities.

Query Speed



- Query time of 1000 random areas on the street network of Europe.

Demo

- Qt client with user-defined drawing rules.
- Java web client with integrated route planning algorithm.

  http://algo2.iti.uni-karlsruhe.de/schultes/hwy/demo/