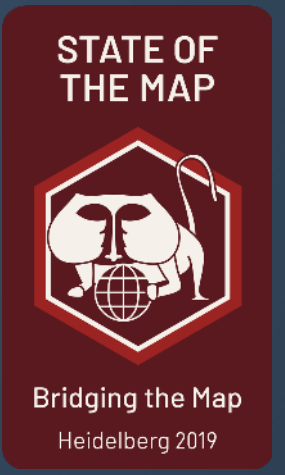
Spatial indexes for OSM in PostGIS

https://slides.com/fxku/sotm19

Felix Kunde

zalando



```
CREATE INDEX pts_spx
ON point_table
USING GIST (geom)
```

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```

BRIN *< v2.3*

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ON point_table
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```

BRIN *< v2.3*

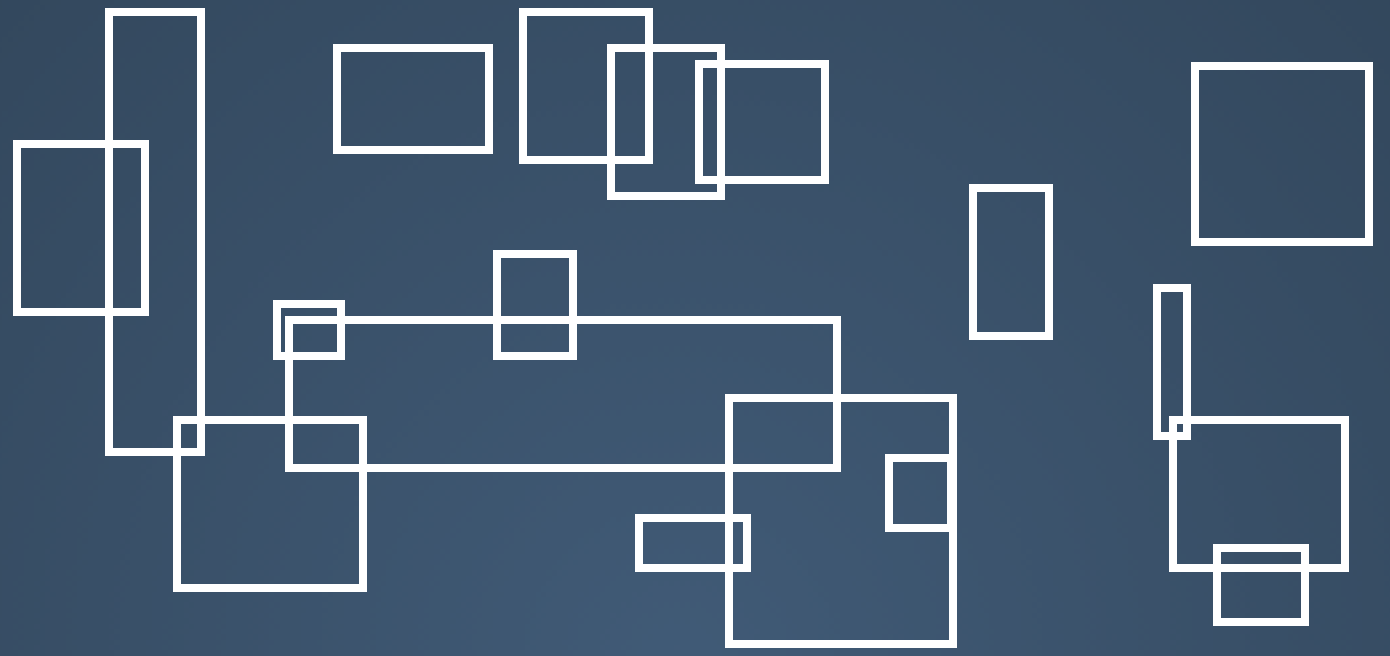
SPGIST *< v2.5*

GiST

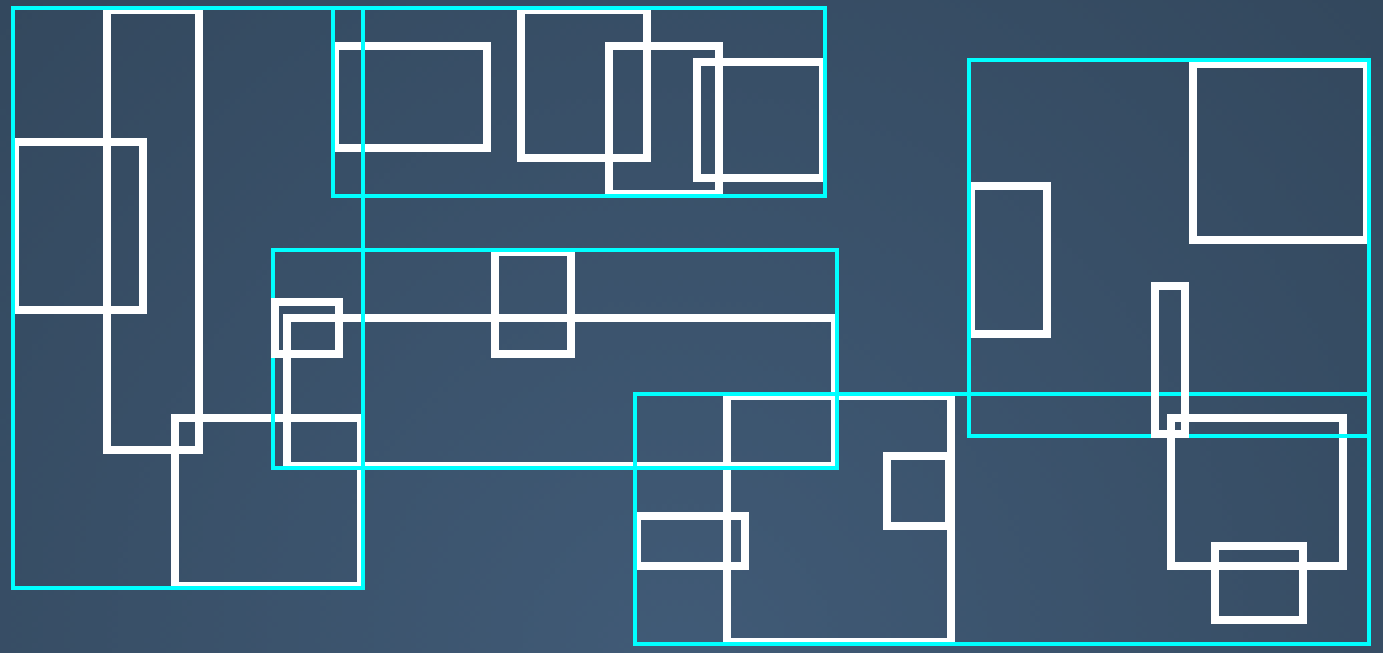
It's a framework

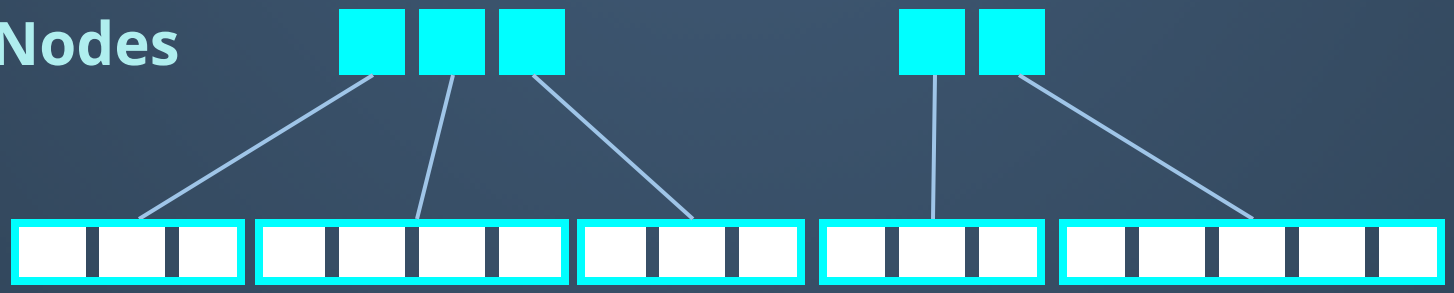
PostGIS > R-Tree

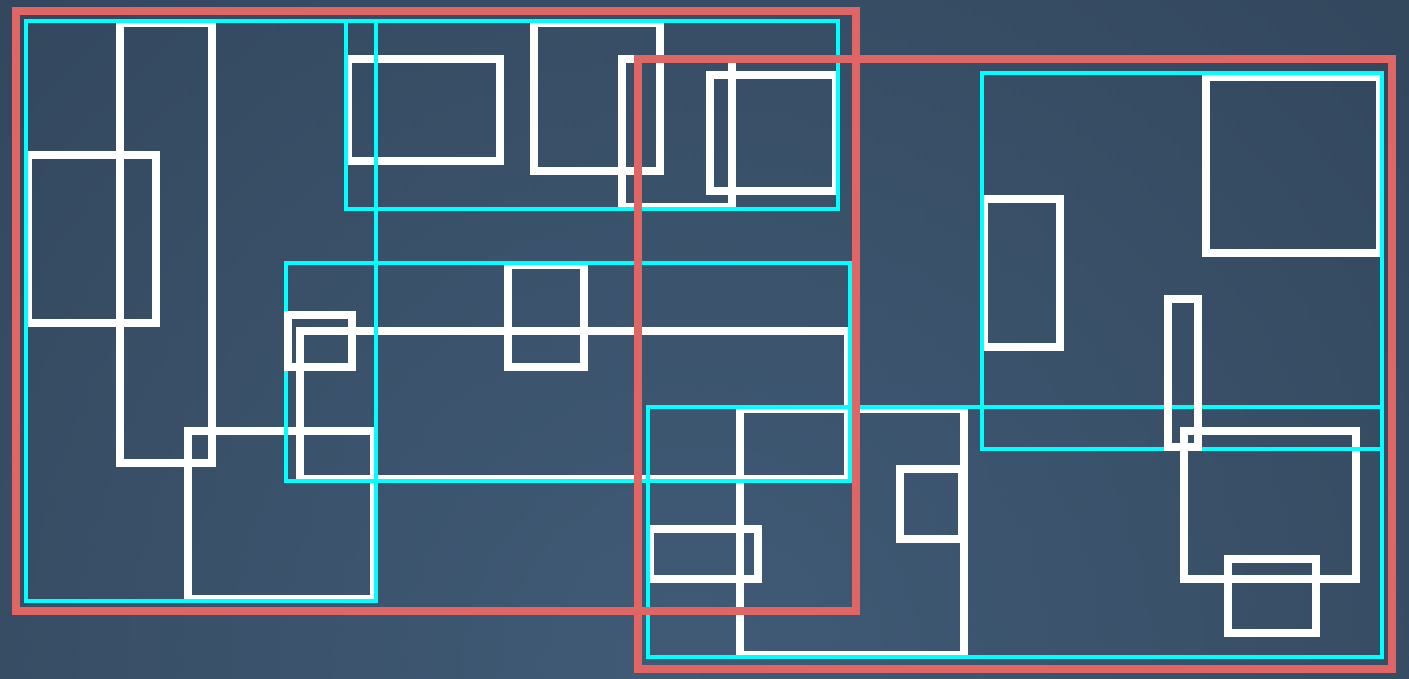
2-nD and kNN support

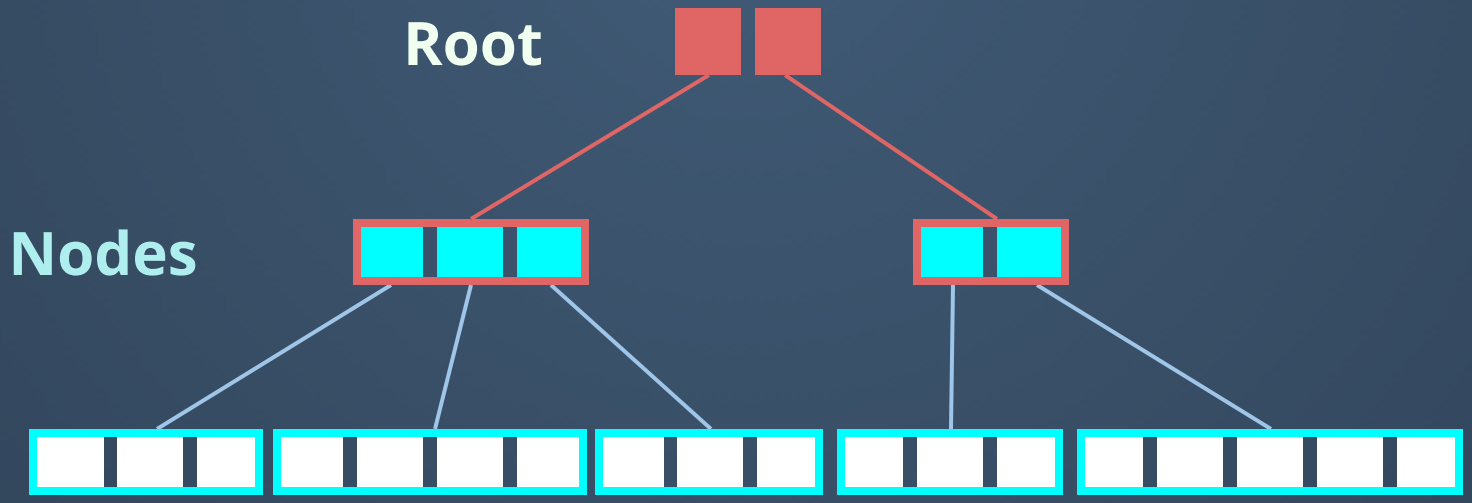


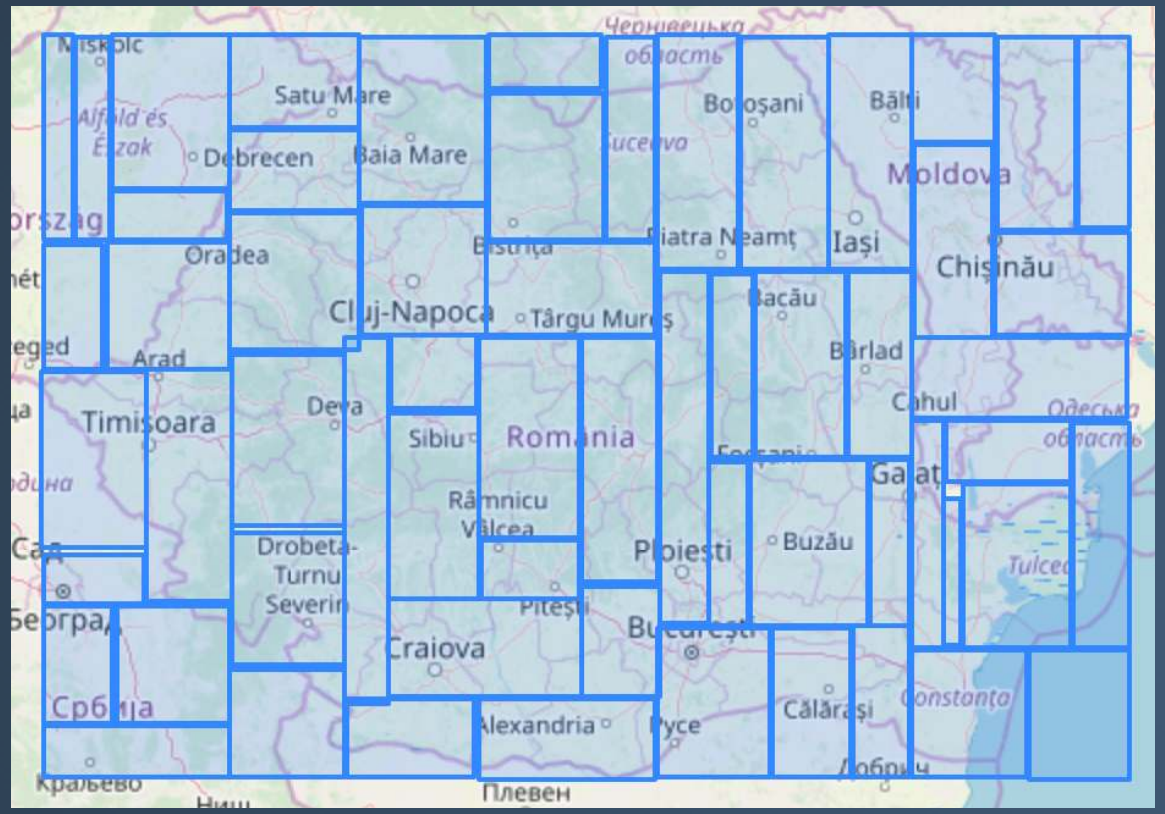
Leaves




Nodes




Root
Nodes



Level 1

Level 2

Produced with Gevel

ST_Intersects in ms

tests	100 k	1 Mio	10 Mio	100 Mio	1 Bn
no index	18.00	87.00	670	6473	135529
bulk	0.21	14.00	19	146	1568
online	0.18	15.00	29	163	1672
vacuum	0.16	0.87	18	145	1551
cluster	0.13	0.64	16	32	214

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BRIN

Block ranges. That's all.

Data should be sorted!

PostGIS > BBox per block

2-4D, no kNN

Block Range Index examples

...	time	geom
...	2019-03-13	POINT(13.8 50)
...	2019-03-13	POINT(13.8 50)
	...	...
	2019-03-14	POINT(13.8 51)
	2019-03-16	POINT(13.7 51)
	...	...
...	2019-03-16	POINT(13.7 51)
...	2019-03-16	POINT(13.7 51)

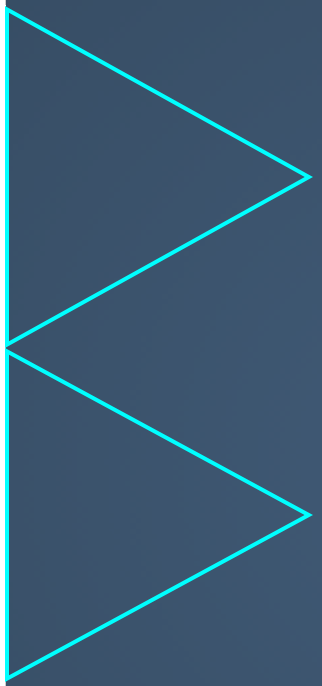
(2019-03-13 09:00:00 , 2019-03-14 11:00:00)

(A-Weg , Grunaer Str.)

BBOX

Block Range Index examples

...	time	geom
...	2019-03-13	POINT(13.8 50)
...	2019-03-13	POINT(13.8 50)
	...	...
	2019-03-14	POINT(13.8 51)
	2019-03-16	POINT(13.7 51)
	...	...
...	2019-03-16	POINT(13.7 51)
...	2019-03-16	POINT(13.7 51)



(2019-03-13 09:00:00 , 2019-03-14 11:00:00)

(A-Weg , Grunaer Str.)

BBOX

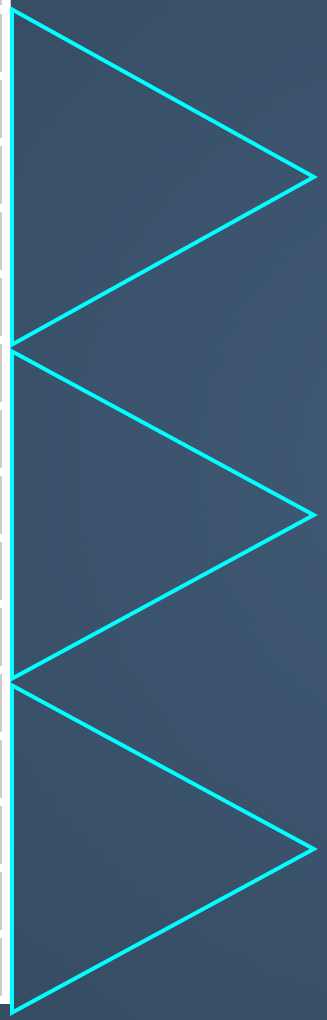
(2019-03-14 11:15:00 , 2019-03-15 18:00:00)

(Grunaer Weg, Nürnberger Str.)

BBOX

Block Range Index examples

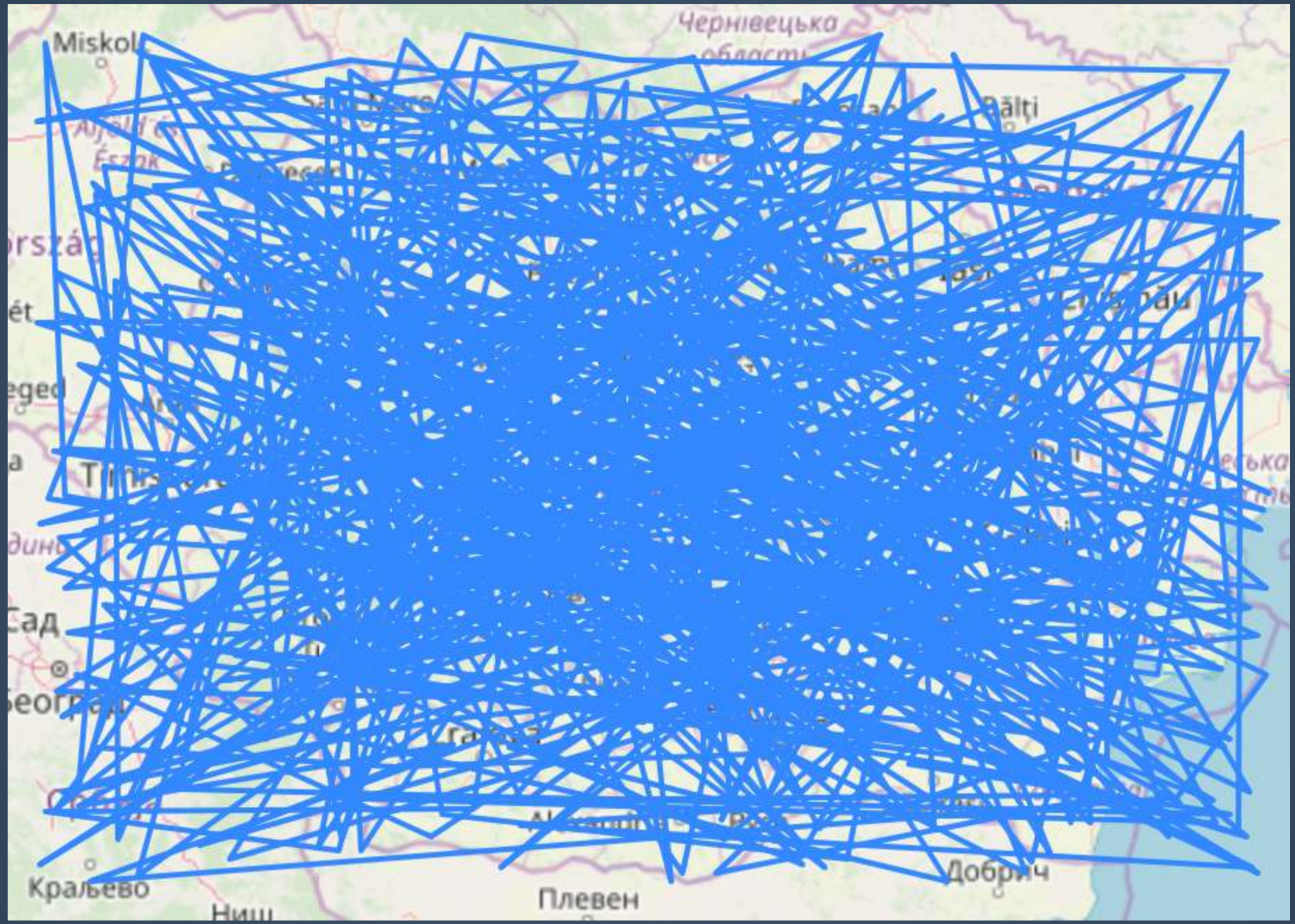
...	time	geom
...	2019-03-13	POINT(13.8 50)
...	2019-03-13	POINT(13.8 50)
	...	...
	2019-03-14	POINT(13.8 51)
	2019-03-16	POINT(13.7 51)
	...	...
...	2019-03-16	POINT(13.7 51)
...	2019-03-16	POINT(13.7 51)



(2019-03-13 09:00:00 , 2019-03-14 11:00:00)
(A-Weg , Grunaer Str.)
BBOX

(2019-03-14 11:15:00 , 2019-03-15 18:00:00)
(Grunaer Weg, Nürnberger Str.)
BBOX

(2019-03-16 09:00:00 , 2019-03-16 17:30:00)
(Oberauer Str. , Zwinglistr.)
BBOX


Miskol
Чернівецька
Plevén
Кральево
Добрич

ORDER BY geom

(PostGIS v3.0 uses Hilbert Curve)

ORDER BY
ST_GeoHash(geom)

```
SET enable_seqscan = false;
```

(discourage Postgres' query planner to use seq scans)

BRIN vs. GiST

tests	100 k	1 Mio	10 Mio	100 Mio	1 Bn
create gist	700 ms	8 sec	2 min	23 min	6 hrs
create brin	24 ms	0.2 sec	2 sec	18 sec	90 sec
size gist	5 MB	50 MB	500 MB	5 GB	50 GB
size brin	24 KB	24 KB	48 KB	376 KB	3,6 MB
duration	x25	x23	x1,4	x1.6	x1.1

sp-GiST

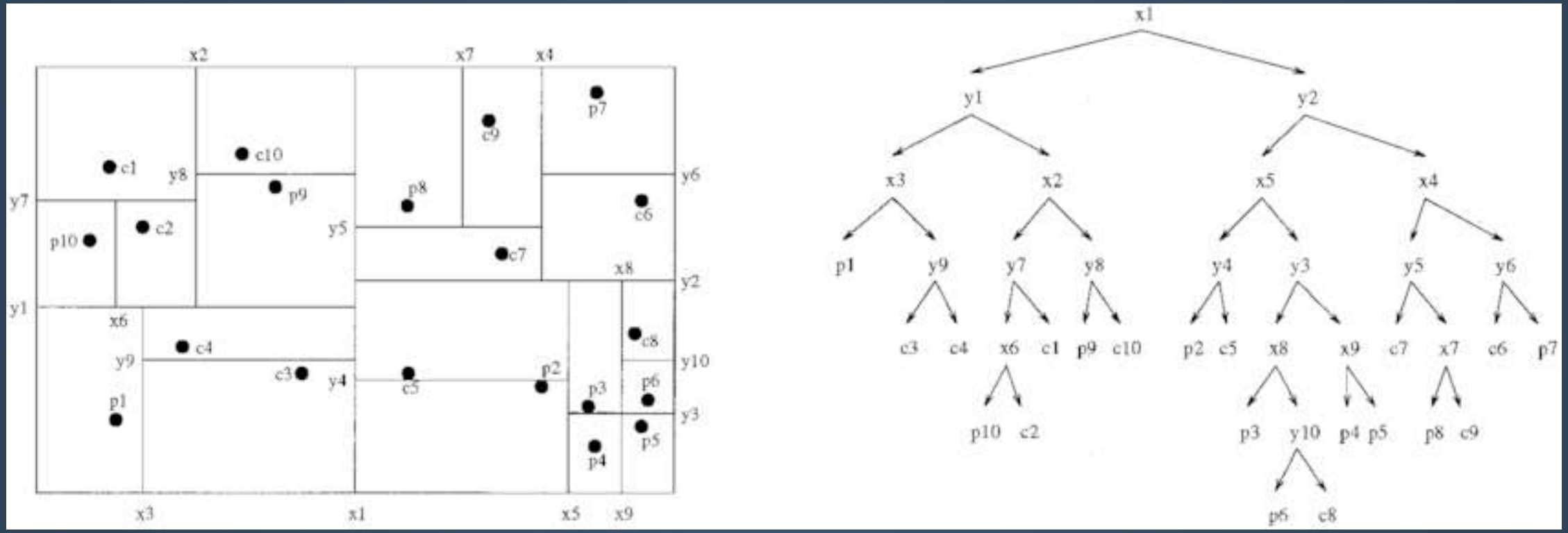
Framework like GIST

Unbalanced tree

No overlaps & prefixes

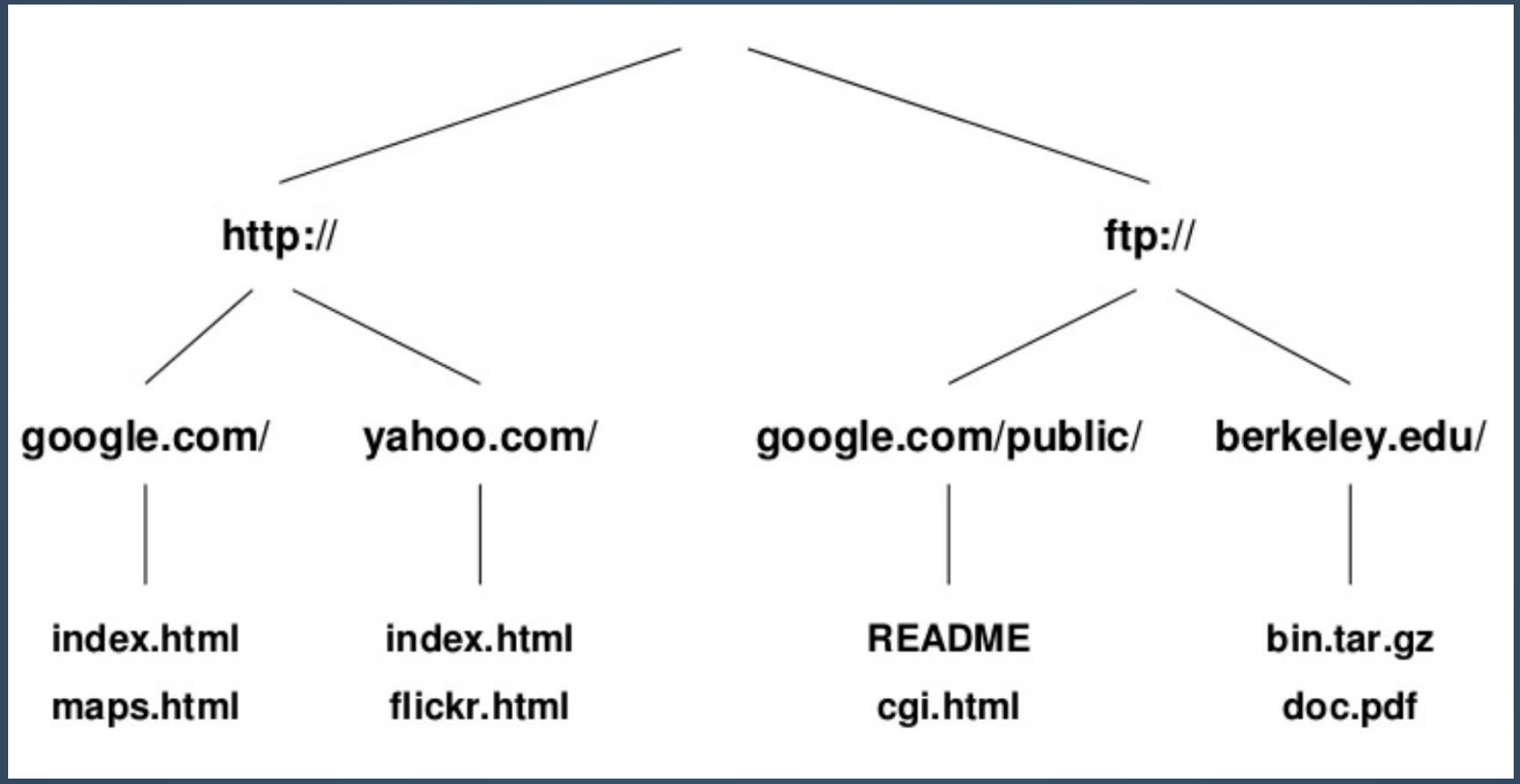
2-nD, no kNN, yet

kd-Tree, Quadtree



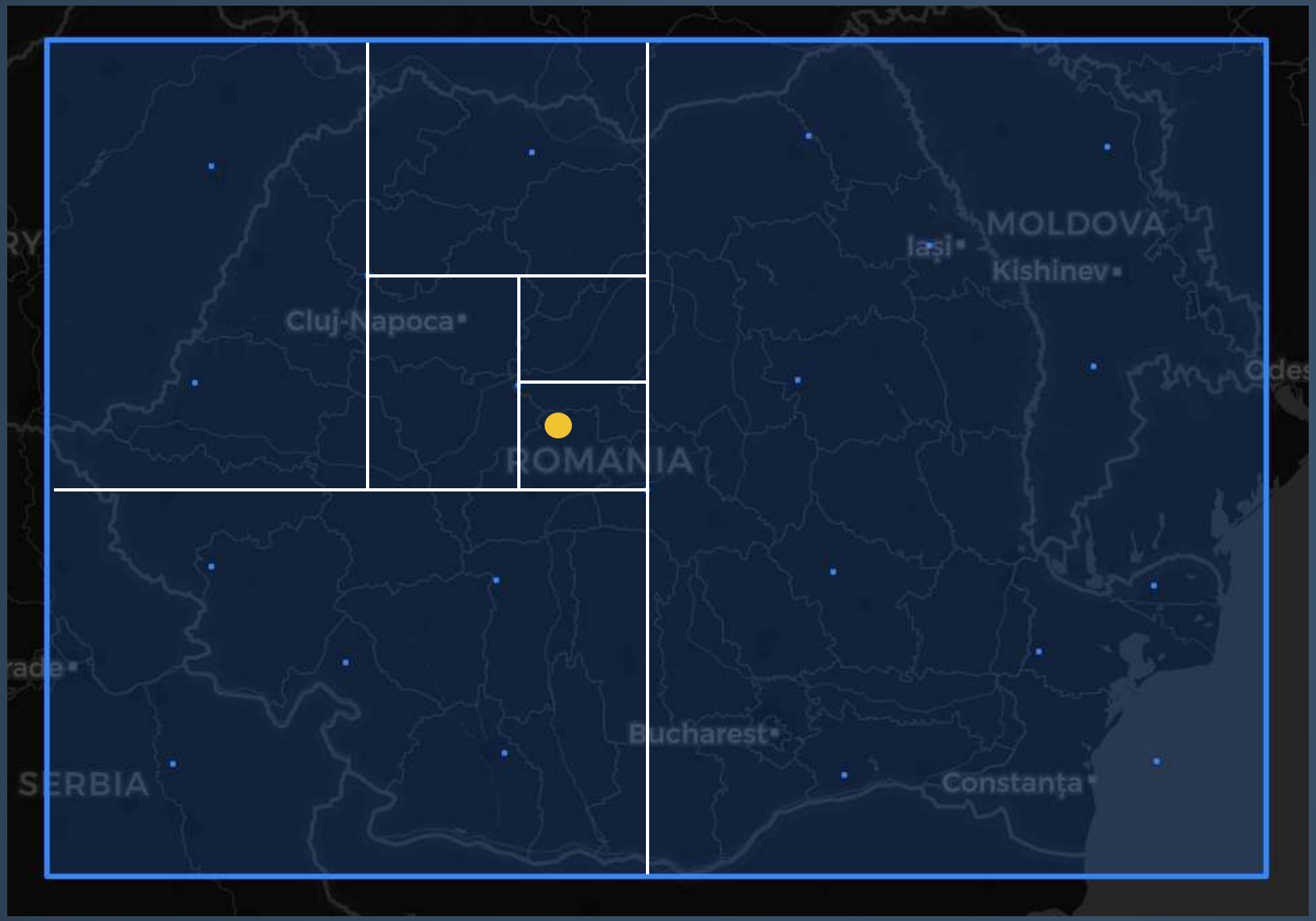
https://www.researchgate.net/figure/Adaptive-k-d-tree_fig9_2334587

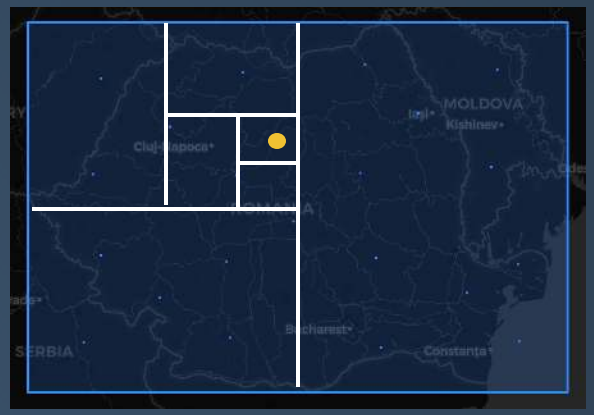
Split values between index and leaf nodes



Momjian 2019: Flexible Indexing with Postgres [PDF]

Trick: No Overlap via more dimensions





Each point you see on the map are in fact 4 bounding boxes which are the prefixes of the sp-GiST tree defining the bounds of child quadrants

sp-GiST vs. GiST

tests	100 k	1 Mio	10 Mio	100 Mio	1 Bn
create gist	700 ms	8 sec	2 min	23 min	6 hrs
create spgist	344 ms	3,7 sec	50 sec	11 min	8 hrs
size gist	5 MB	50 MB	500 MB	5 GB	50 GB
size spgist	4,5 MB	44 MB	440 MB	4.3 GB	43 GB
duration	x0.85	x1	x1	x1	x1.1

Thematic filters

Multi-column index

```
CREATE INDEX idx ON planet_osm_point
USING GIST (way, power);
```

Requires btree_gist extension

Spatial column first as it is more selective

Less read from heap

Index will be bigger, combine with ...

Partial index

```
CREATE INDEX idx ON planet_osm_point
USING GIST (way)
WHERE power = 'pole';
```

Smaller index, less IO overhead

Very specific to a certain task

OSM people do this

Covering index

```
CREATE INDEX idx ON planet_osm_point
USING GIST (way)
INCLUDE (power);
```

"Payload" only in the leaves (not sorted)

No big speed difference to multi-column index

GiST support in Postgres 12

Btw: Index-only scans?

Not possible due to compression

Requires new index tuple format with SRID

For small geoms (Points, BBox, ..?)

Breaking all GiSTs out there?

GeoHash index

```
CREATE INDEX idx ON planet_osm_point
USING BTREE (
  ST_GeoHash(ST_Transform(way,4326)), power
)
WHERE power IS NOT NULL;
```

BTREE benefits (parallel build, index-only-scan)

Spatial filtering tricky (GeoHash grid)

Slower, so only useful for table clustering

Radix tree

```
CREATE INDEX idx ON planet_osm_point
USING SPGIST (
  ST_GeoHash(ST_Transform(way,4326)) text_ops
)
WHERE power IS NOT NULL;
```

GeoHash and SPGIST seem like a great fit

LIKE not supported, but can use ranges

Slow (only two prefixes on small dataset)

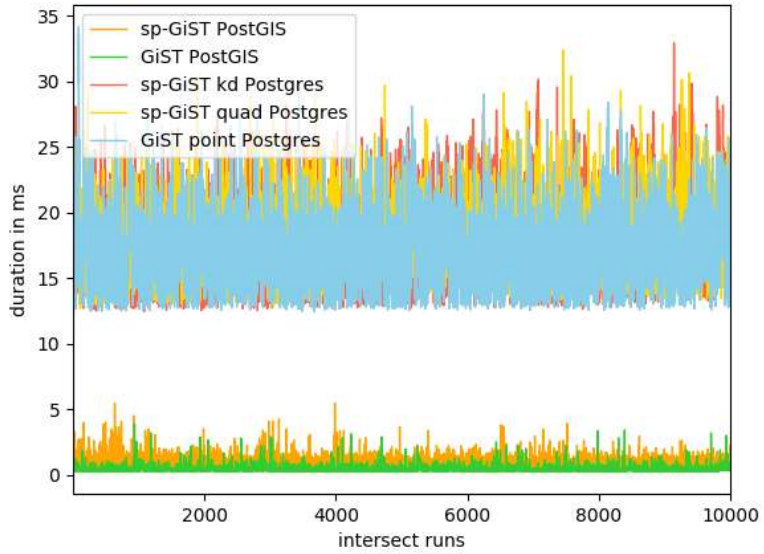
Postgres geometry

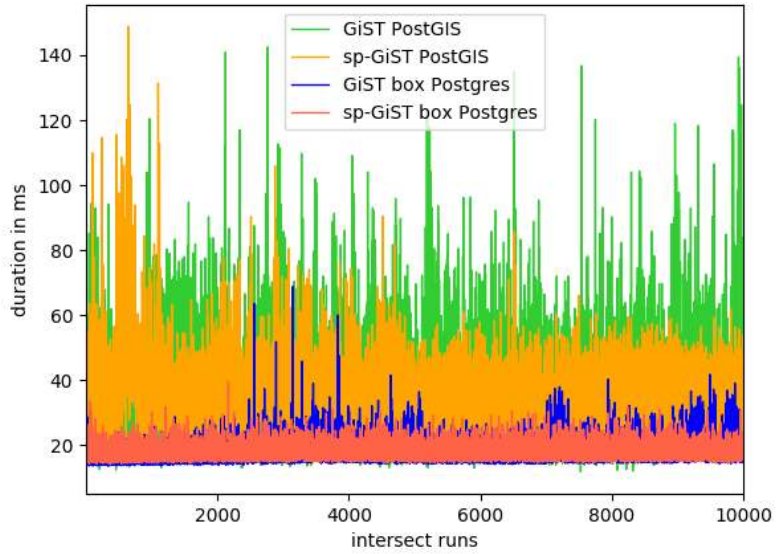
```
CREATE INDEX idx ON planet_osm_point
USING SPGIST (
  CAST (way AS point) quad_point_ops
)
WHERE power IS NOT NULL;
```

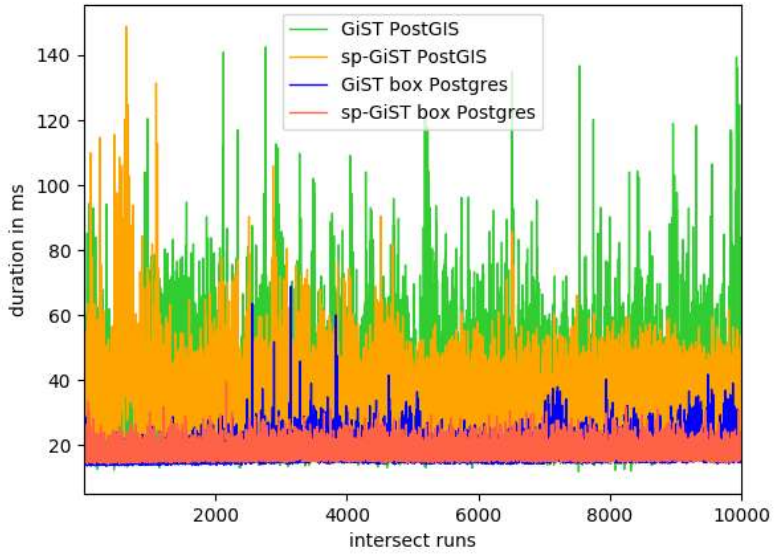
Queries need casting but it works

And performance is good (smaller tuple layout)

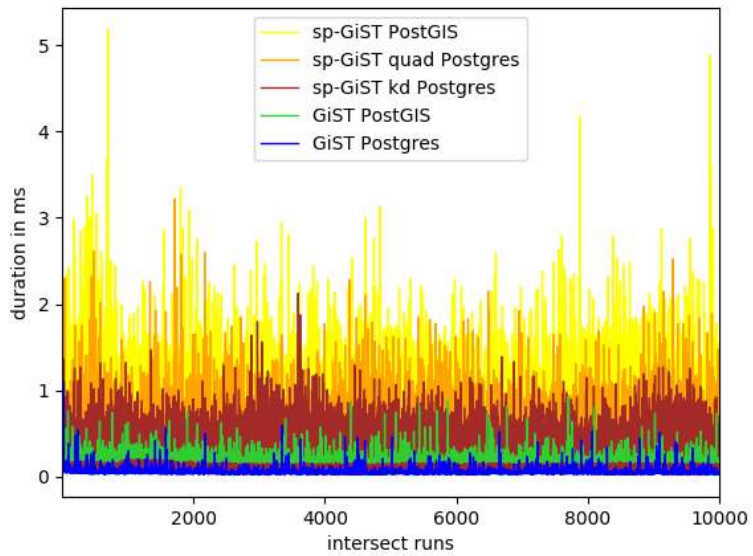
```
SELECT 1 FROM planet_osm_[point|line|polygon]
 WHERE CAST(way AS point) <@ [filter-box]
   AND _ST_Intersects(way, [filter-buffer]);
```

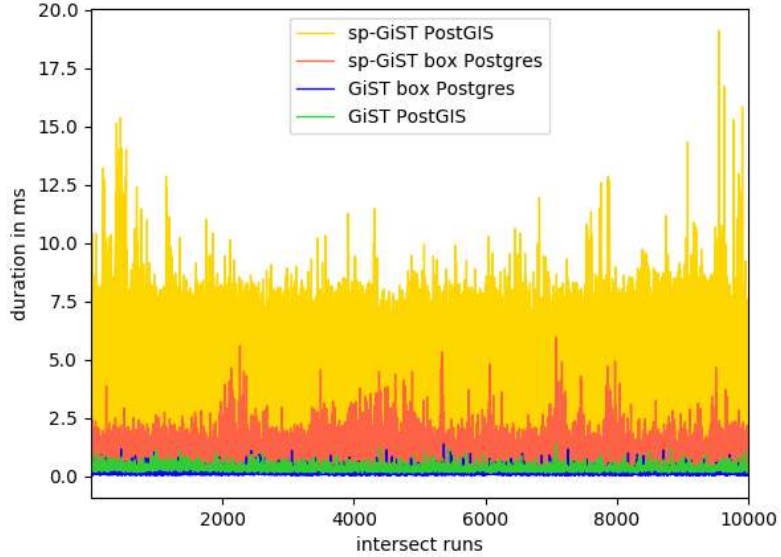


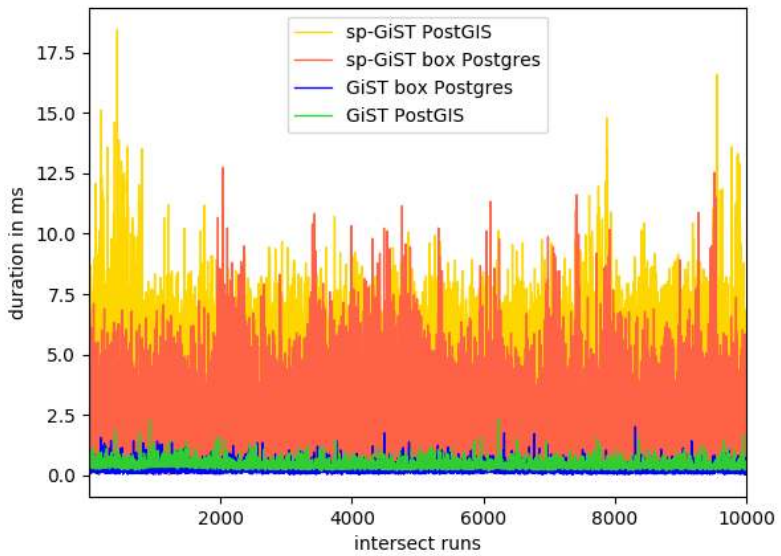




```
SELECT 1 FROM planet_osm_[point|line|polygon]
 WHERE CAST(way AS point) <@ [filter-box];
```







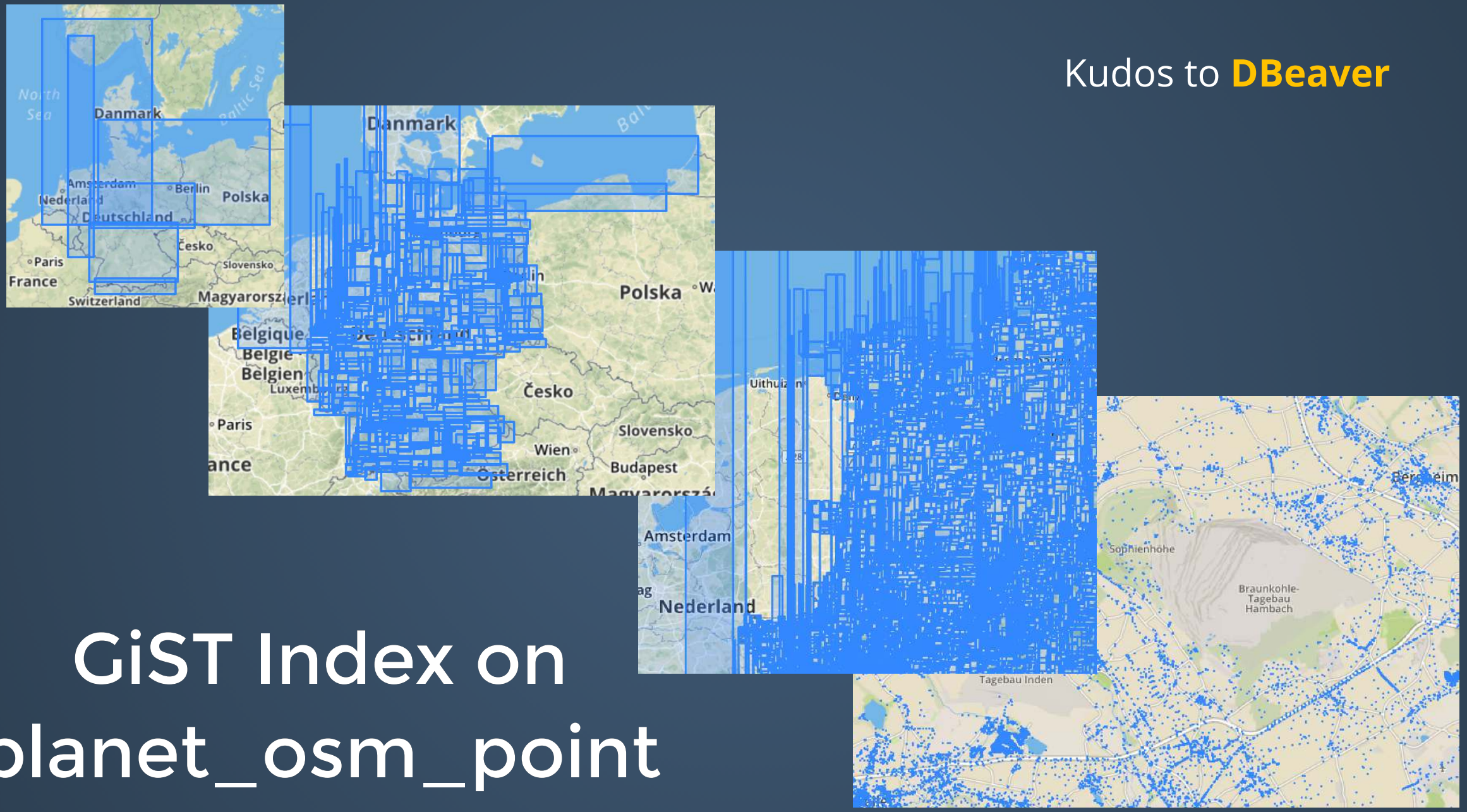
OSM Experiments

			
Points	0.5 Mio, 128 MB, **12%** 132, 53, 0.2 MB	1.7 Mio, 0.4 GB, **13%** 96, 92, 0.5 MB	11.7 Mio, 3 GB, **11%** 630, 600, 0.1 MB
Lines	0.5 Mio, 250 MB, **43%** 132, 53, 0.2 MB	2 Mio, 1 GB, **44%** 230, 93, 0.6 MB	14.37 Mio, 7 GB, **42%** 1500, 600, 0.2 MB
Polygons	1.2 Mio, 533 MB, **38%** 132, 53, 0.2 MB	5 Mio, 2.3 GB, **39%** 560, 220, 0.2 MB	35.6 Mio, 16 GB, **39%** 3800, 1500, 0,5 MB

Rowcount, Tablesize, Geom. size to table size

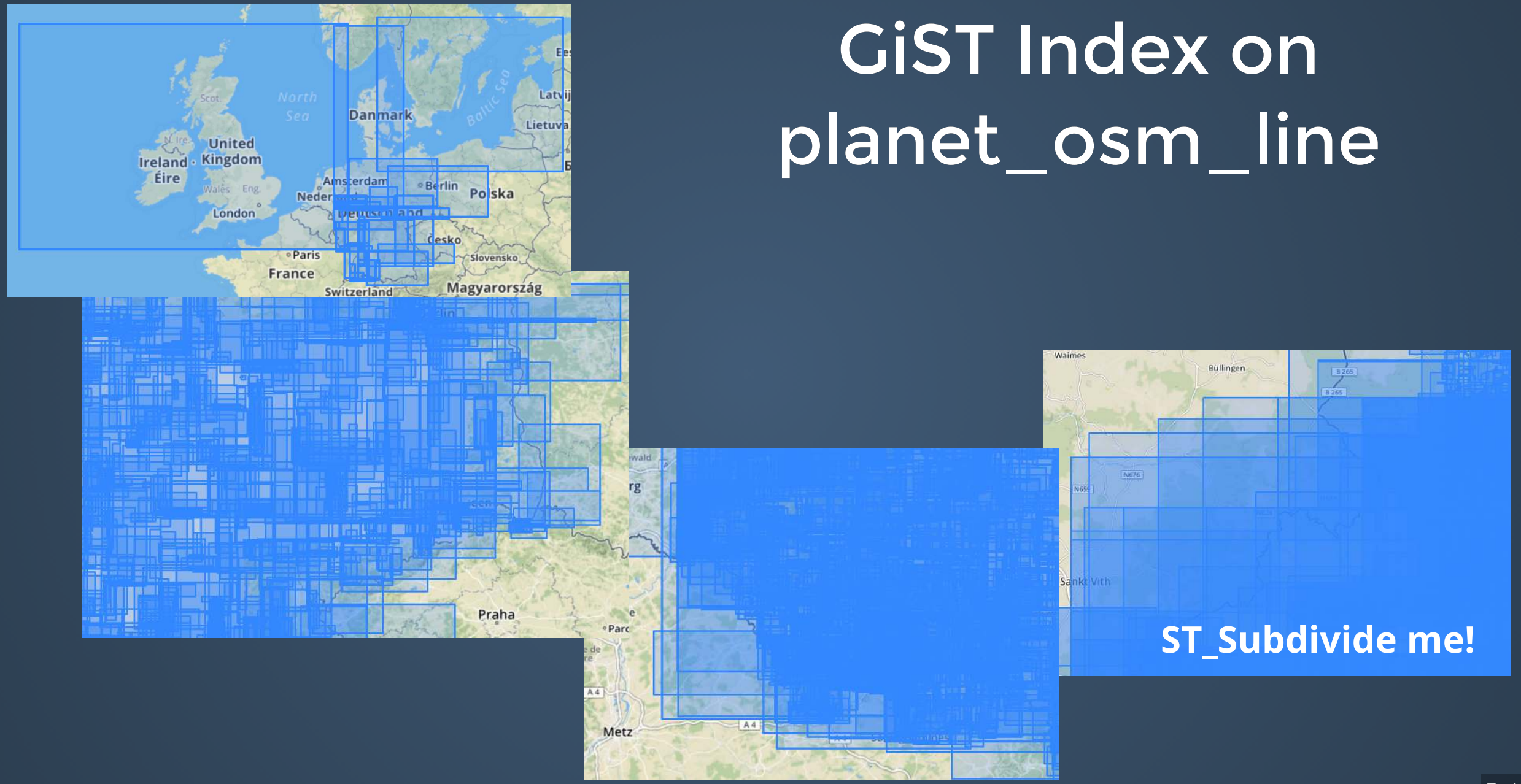
sizes of GiST, sp-GiST and BRIN

Kudos to **DBeaver**

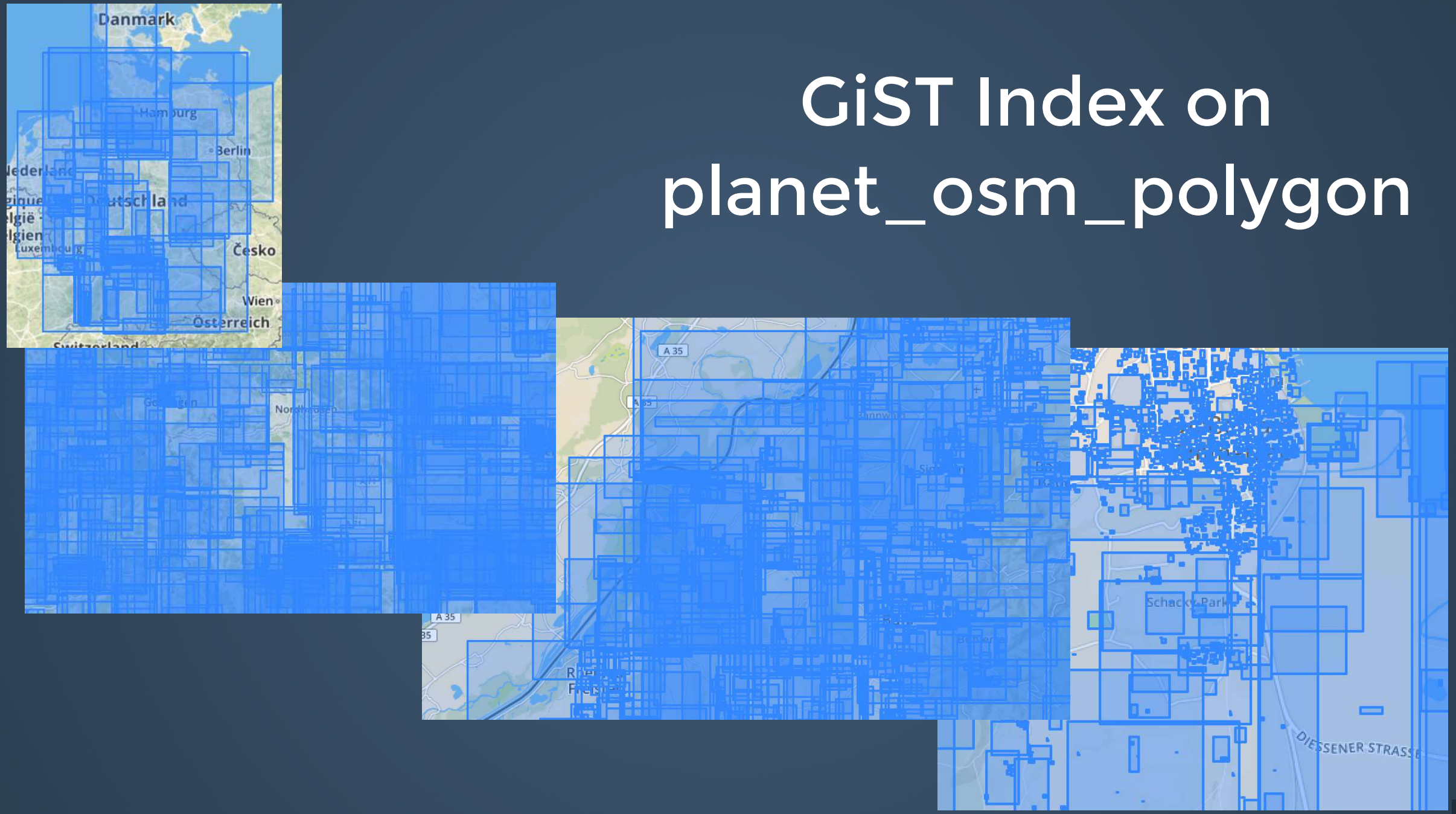


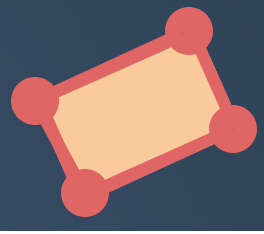
GiST Index on planet_osm_point

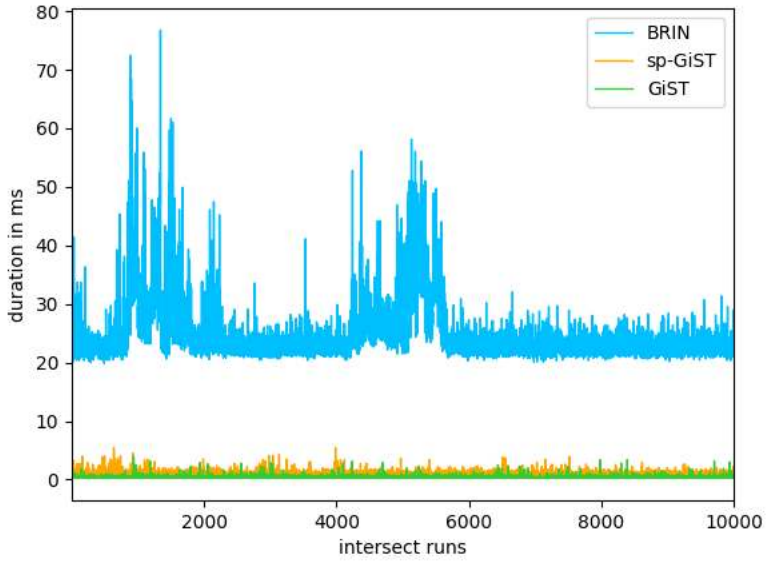
GiST Index on planet_osm_line

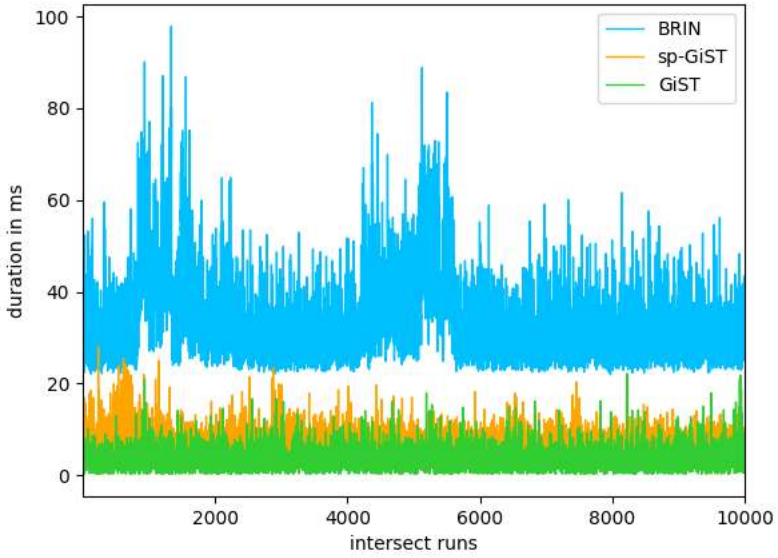


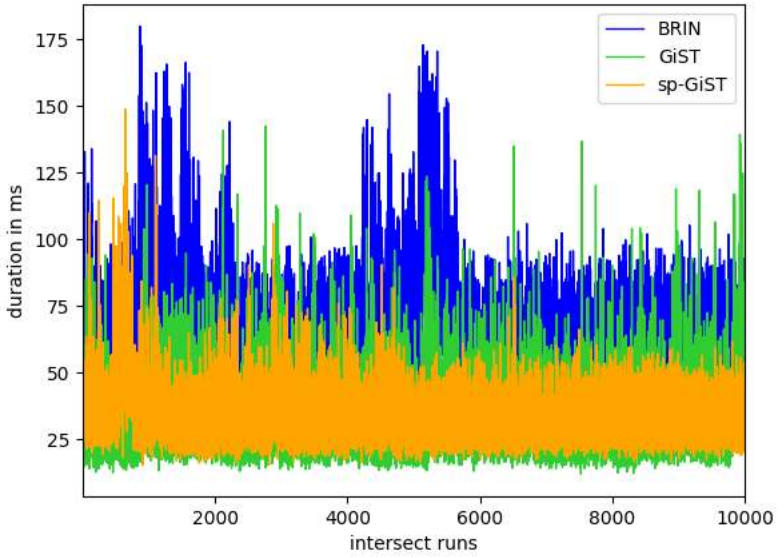
GiST Index on planet_osm_polygon







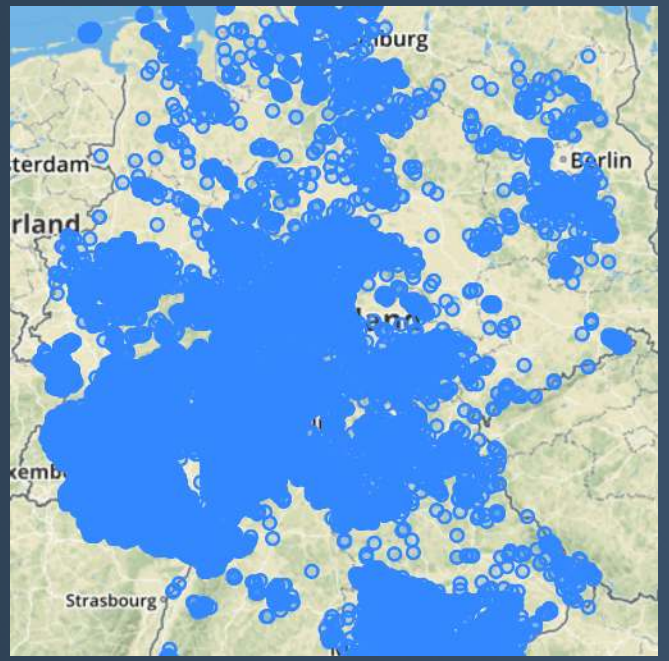




The more data, the closer the gap to BRIN

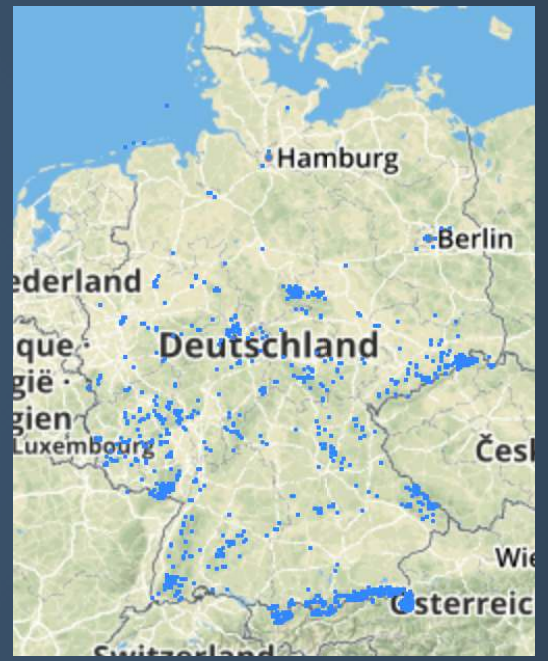
GiST and sp-GiST comparable on Polygons

highway:
emergency_access_point
~ 25.000



highway: motorway
~ 65.000

natural: bare_rock
~ 25.000



sp-GiST slightly faster for points and poylgons

Higher hit-rate of shared buffers (when is this bad?)

```
CREATE INDEX highway_eap_gist ON planet_osm_point USING GIST (way) WHERE highway = 'emergency_access_point';
CREATE INDEX highway_eap_spgist ON planet_osm_point USING SPGIST (way) WHERE highway = 'emergency_access_point';

EXPLAIN (ANALYZE, Buffers)
SELECT 1 FROM planet_osm_point, random_points
 WHERE ST_Intersects(way,ST_Buffer(geom,1000))
   AND highway = 'emergency_access_point';

GIST

Nested Loop  (cost=0.28..29261.90 rows=83000 width=4) (actual time=0.685..452.657 rows=817 loops=1)
  Buffers: shared hit=21756
  ->  Seq Scan on random_points  (cost=0.00..94.00 rows=10000 width=32) (actual time=0.011..1.977 rows=10000 loops=1)
        Buffers: shared hit=84
  ->  Index Scan using highway_eap_gist on planet_osm_point  (cost=0.28..2.92 rows=1 width=32) (actual time=0.018..0.019 rows=0 loops=10000)
        Index Cond: (way && st_buffer(random_points.geom, '1000'::double precision))
        Filter: _st_intersects(way, st_buffer(random_points.geom, '1000'::double precision))
        Rows Removed by Filter: 0
        Buffers: shared hit=21672
Planning Time: 0.201 ms
Execution Time: 452.791 ms

sp-GIST

Nested Loop  (cost=0.28..29274.00 rows=83000 width=4) (actual time=1.267..362.863 rows=817 loops=1)
  Buffers: shared hit=39917
  ->  Seq Scan on random_points  (cost=0.00..94.00 rows=10000 width=32) (actual time=0.019..1.690 rows=10000 loops=1)
        Buffers: shared hit=84
  ->  Index Scan using highway_eap_spgist on planet_osm_point  (cost=0.28..2.92 rows=1 width=32) (actual time=0.011..0.012 rows=0 loops=10000)
        Index Cond: (way && st_buffer(random_points.geom, '1000'::double precision))
        Filter: _st_intersects(way, st_buffer(random_points.geom, '1000'::double precision))
        Rows Removed by Filter: 0
        Buffers: shared hit=39833
Planning Time: 0.347 ms
Execution Time: 363.027 ms
```

```
CREATE INDEX motorway_gist ON planet_osm_line USING GIST (way) WHERE highway = 'motorway';
CREATE INDEX motorway_spgist ON planet_osm_line USING SPGIST (way) WHERE highway = 'motorway';

EXPLAIN (ANALYZE, Buffers)
SELECT 1 FROM planet_osm_line, random_points
 WHERE ST_Intersects(way,ST_Buffer(geom,1000))
   AND highway = 'motorway';

GIST

Nested Loop  (cost=0.28..93512.50 rows=229587 width=4) (actual time=3.490..457.310 rows=3023 loops=1)
  Buffers: shared hit=28119
  ->  Seq Scan on random_points  (cost=0.00..94.00 rows=10000 width=32) (actual time=0.007..1.564 rows=10000 loops=1)
        Buffers: shared hit=84
  ->  Index Scan using motorway_gist on planet_osm_line  (cost=0.28..9.34 rows=2 width=218) (actual time=0.016..0.024 rows=0 loops=10000)
        Index Cond: (way && st_buffer(random_points.geom, '1000'::double precision))
        Filter: _st_intersects(way, st_buffer(random_points.geom, '1000'::double precision))
        Rows Removed by Filter: 0
        Buffers: shared hit=28035
Planning Time: 0.278 ms
Execution Time: 457.651 ms

sp-GIST

Nested Loop  (cost=0.28..93497.10 rows=229587 width=4) (actual time=8.248..653.375 rows=3023 loops=1)
  Buffers: shared hit=294815
  ->  Seq Scan on random_points  (cost=0.00..94.00 rows=10000 width=32) (actual time=0.010..1.836 rows=10000 loops=1)
        Buffers: shared hit=84
  ->  Index Scan using motorway_spgist on planet_osm_line  (cost=0.28..9.34 rows=2 width=218) (actual time=0.032..0.041 rows=0 loops=10000)
        Index Cond: (way && st_buffer(random_points.geom, '1000'::double precision))
        Filter: _st_intersects(way, st_buffer(random_points.geom, '1000'::double precision))
        Rows Removed by Filter: 0
        Buffers: shared hit=294731
Planning Time: 0.345 ms
Execution Time: 653.781 ms
```

Conclusion & Outlook

Stick with GiST

But give BRIN a try

Use partial indexes

sp-GiST for unbalanced themes

Keep your table stats up-to-date

Parallel queries!

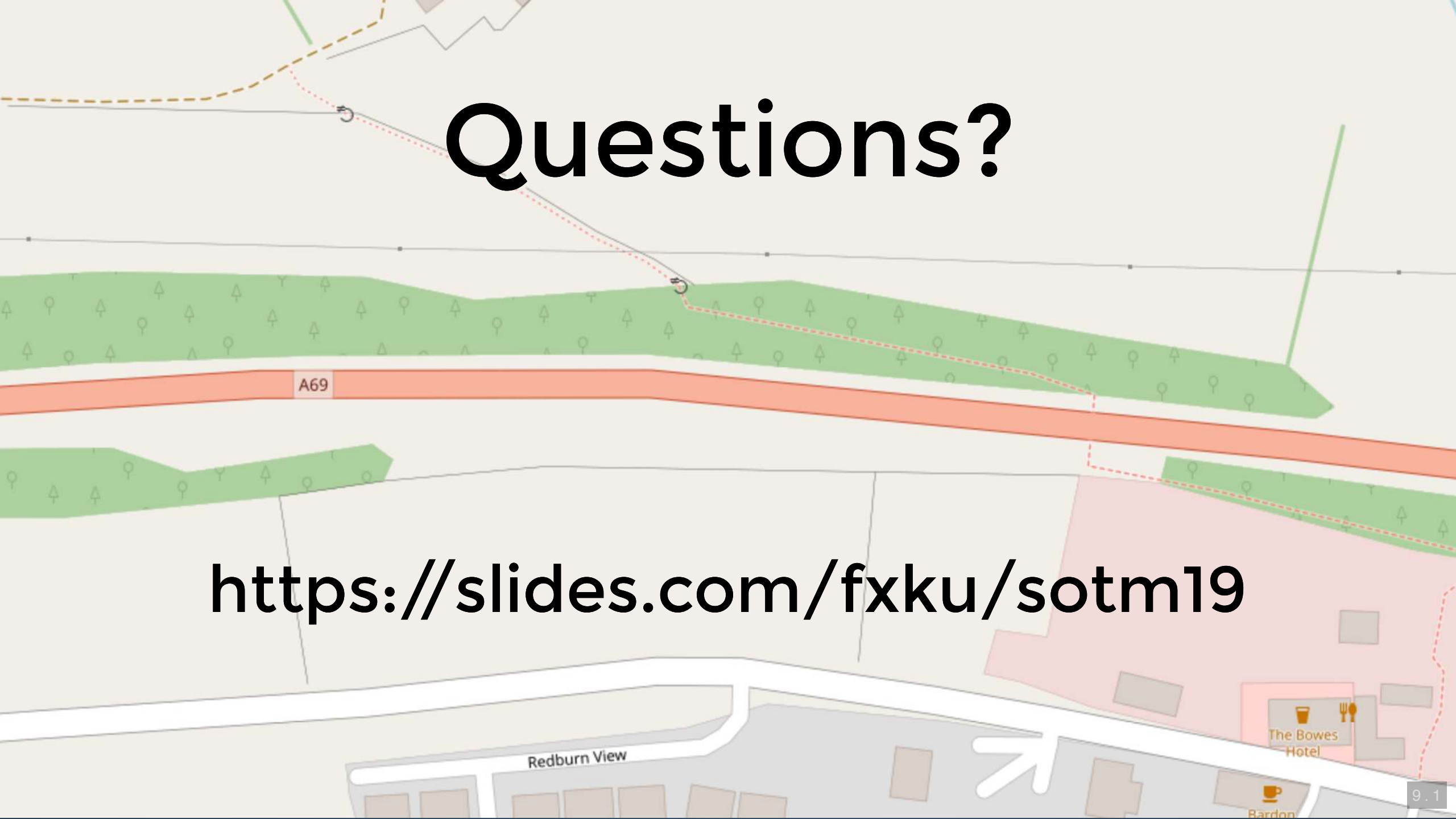
Faster index building!

Index-only scans?

New table access methods?

Questions?

https://slides.com/fxku/sotm19



Used hardware

Tuxedo Infinity Book 13
Intel i7-8550U CPU 1.80GHz
Quadcore, 8 CPUs
32 GB RAM
500GB SSD disk

Repo

github.com/FxKu/postgis_indexing

PostgreSQL config

PostgreSQL 11 & PostGIS 2.5
shared_buffers = 16 GB
work_mem = 128 MB
maintenance_work_mem = 4 GB
min/max_wal_level = 16/4 GB
checpoint_timeout = 30 min
checkpoint_completion_target = 0.9
random_page_cost = 1.1
cpu_tuple_cost = 0.001
cpu_index_tuple_cost = 0.001
effective_cache_size = 24 GB
default_statistics_target = 500

More links

Pettus 2019: Look it up - Practical PostgreSQL indexing [PDF]

Rogov 2019: Indexes in PostgreSQL - sp-GiST (Blog)

Katz 2018: Why covering indexes are helpful (Blog)

Albe 2019: Optimizer support for functions (Blog)

Wienand 2019: Be inclusive (Covering indexes) [PDF]