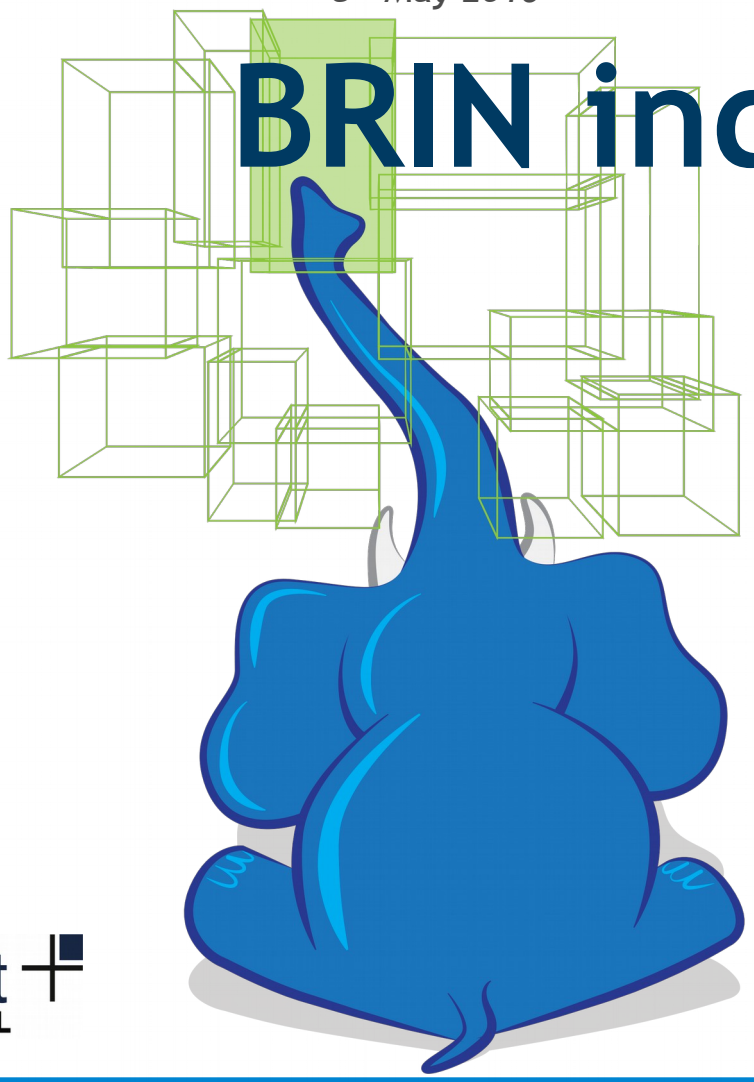
PGDay@FOSS4G.NA 2016

Raleigh, NC

3rd May 2016

FOSS4G NORTH AMERICA 2016

BRIN indexes on geospatial databases



2ndQuadrant
Professional PostgreSQL

www.2ndquadrant.com

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

~$ whoami

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Professional PostgreSQL

Giuseppe Broccolo, PhD

PostgreSQL & PostGIS consultant

@giubro gbroccolo7 gbroccolo gemini__81

giuseppe.broccolo@2ndquadrant.it

Indexes & PostgreSQL

- Binary structures on disc:
  - Indexing organised in **nodes** into 8kB pages
  - Speed up data access: ~O(log N)
  - High performance until the index can be contained in RAM
    - Size: ~O(N)

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

Geospatial indexes in PostgreSQL

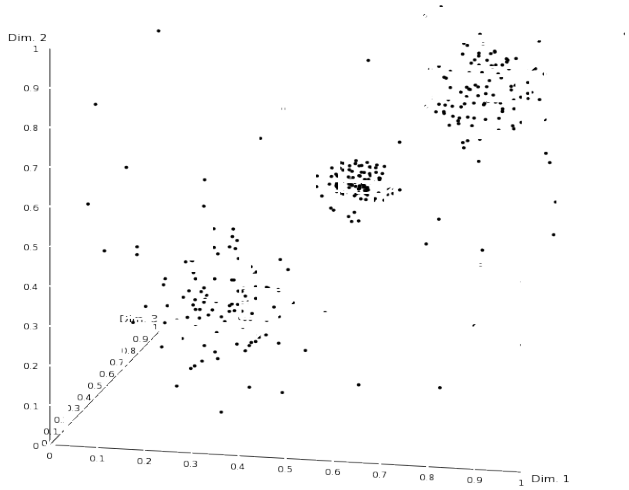
- All datatypes can be indexed in principle...
  - ...just define the needed **OpClass**!
    - Operators & Support functions

- Geospatial data can be larger than 8kB
  - A single node cannot be contained into a single page
  - GiST indexing allows to reduce the information that has to be indexed ***compressing*** the PostgreSQL in-core geospatial objects into its ***bounding box***

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

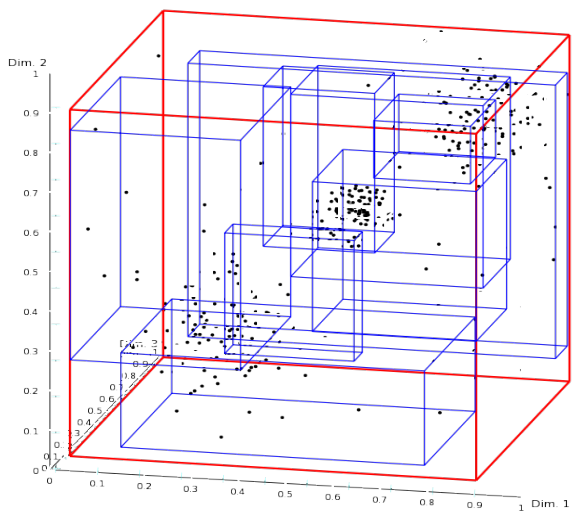
PostGIS datatypes

In PostGIS (since v0.6) **`geometry`**/**`geography`** are converted into their float-precision bounding boxes

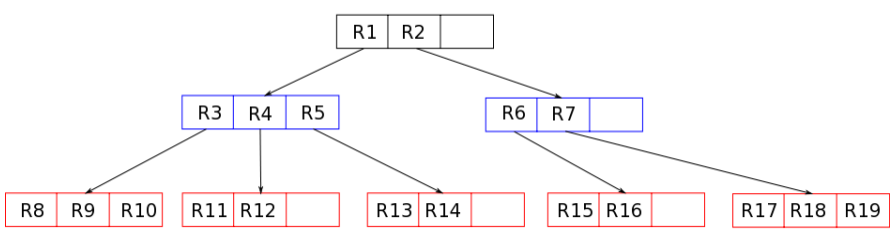


PostGIS datatypes

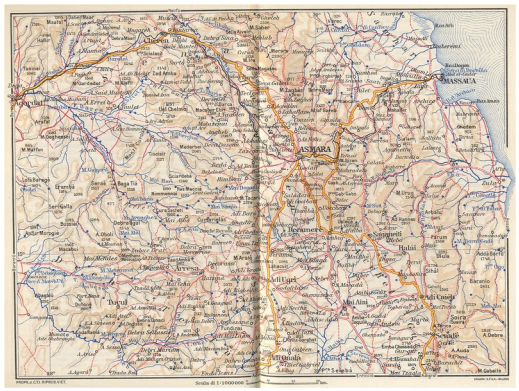
In PostGIS (since v0.6) **`geometry`**/**`geography`** are converted into their float-precision bounding boxes



`gidx`/**`box2df`** are then used as storage datatype to populate the index's nodes

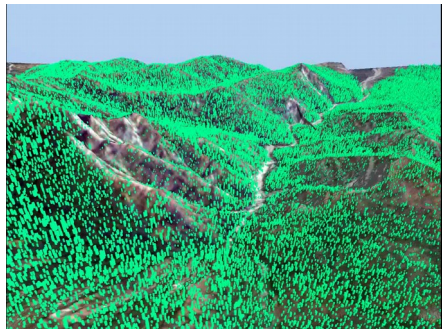


GIS & BigData



Maps of entire countries

LiDAR surveys



It's relatively easy to have to work with terabytes of geospatial data…

…can indexes be contained in RAM?

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

A new index: Block Range INdexing

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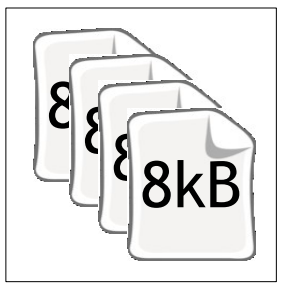
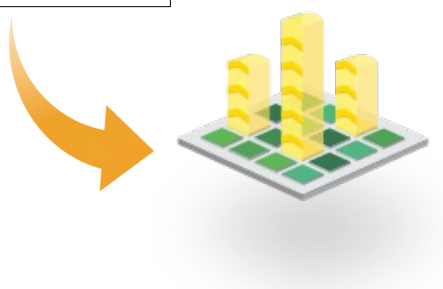
S. Riggs, A. Herrera

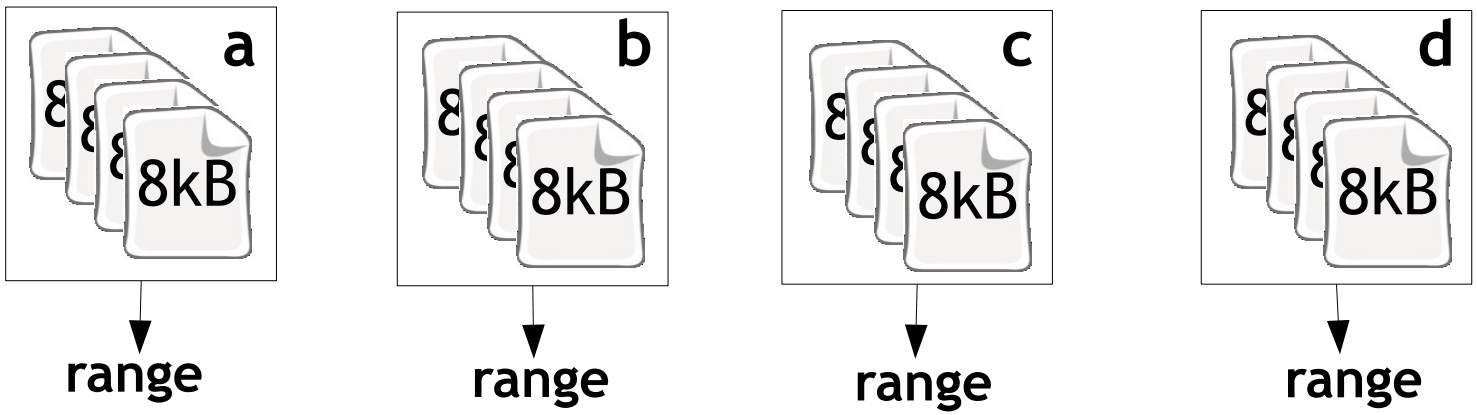


- **BLOCK**: set of physically adjacent 8kB pages
- **RANGE**: boundaries of data contained in the block
- **granularity: `pages_per_range`**
  - default: blocks of 128 pages

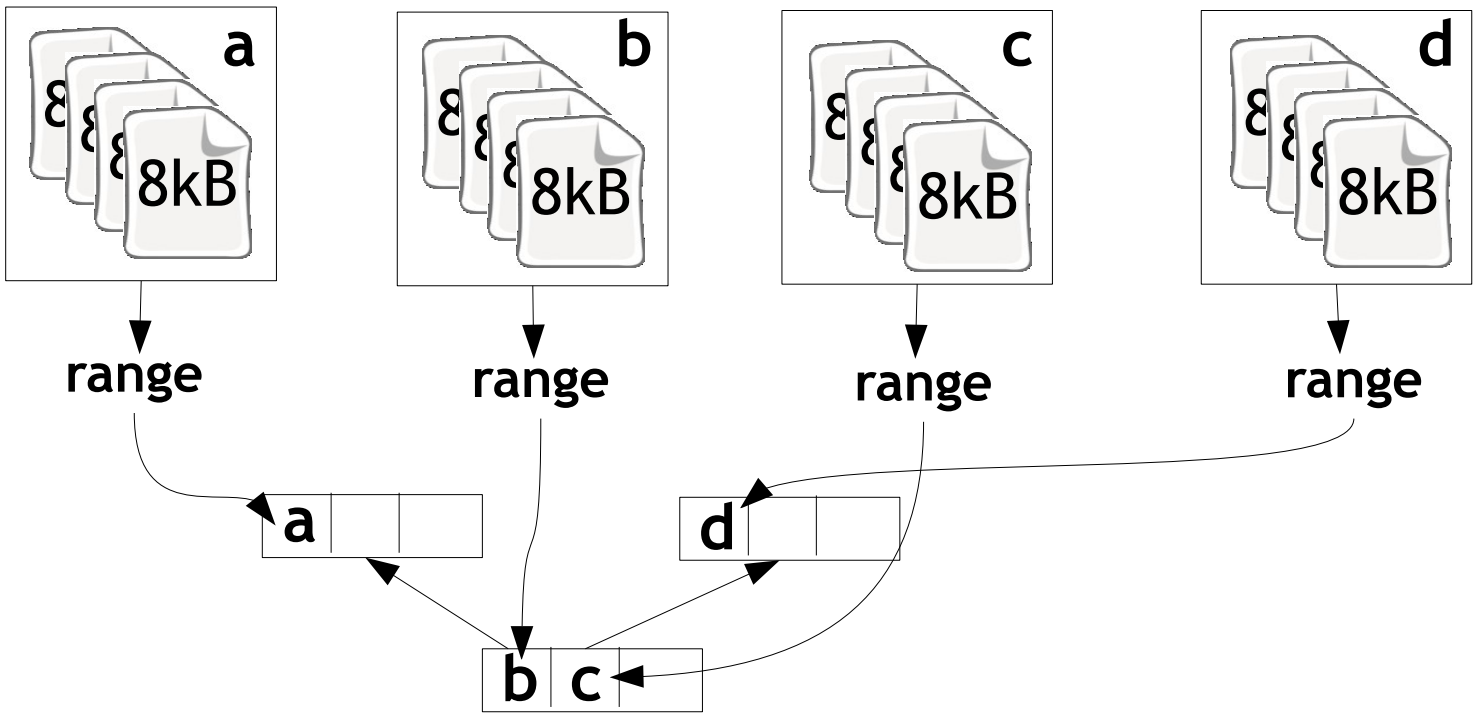


```
CREATE INDEX idx ON table USING brin(column) WITH (pages_per_range=10);
```

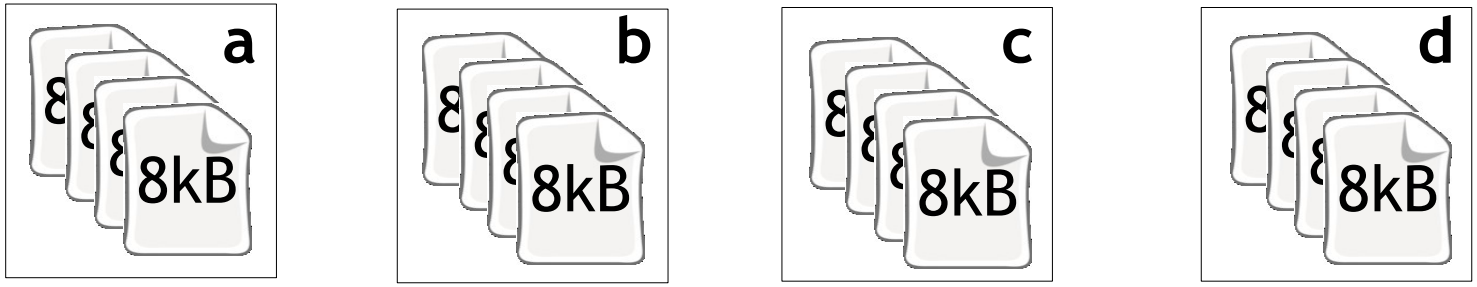
BRIN - indexing

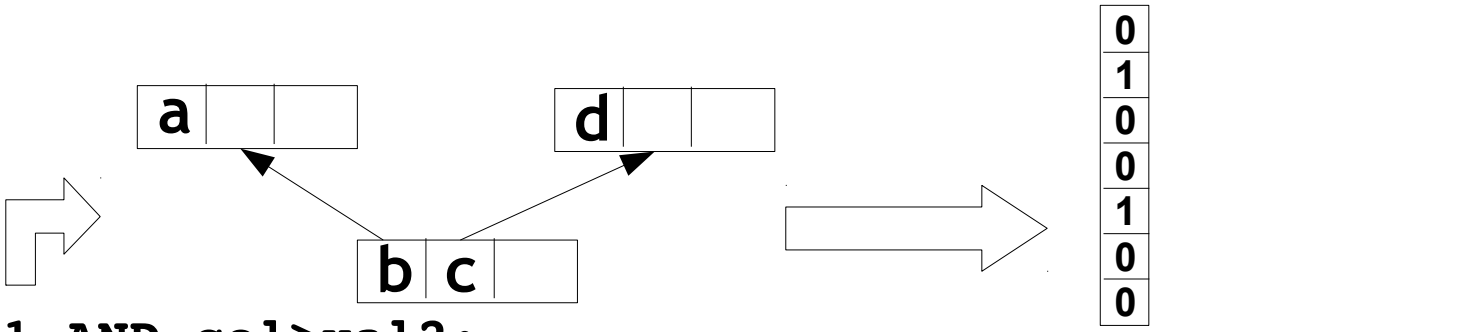


BRIN - indexing



BRIN - scan execution

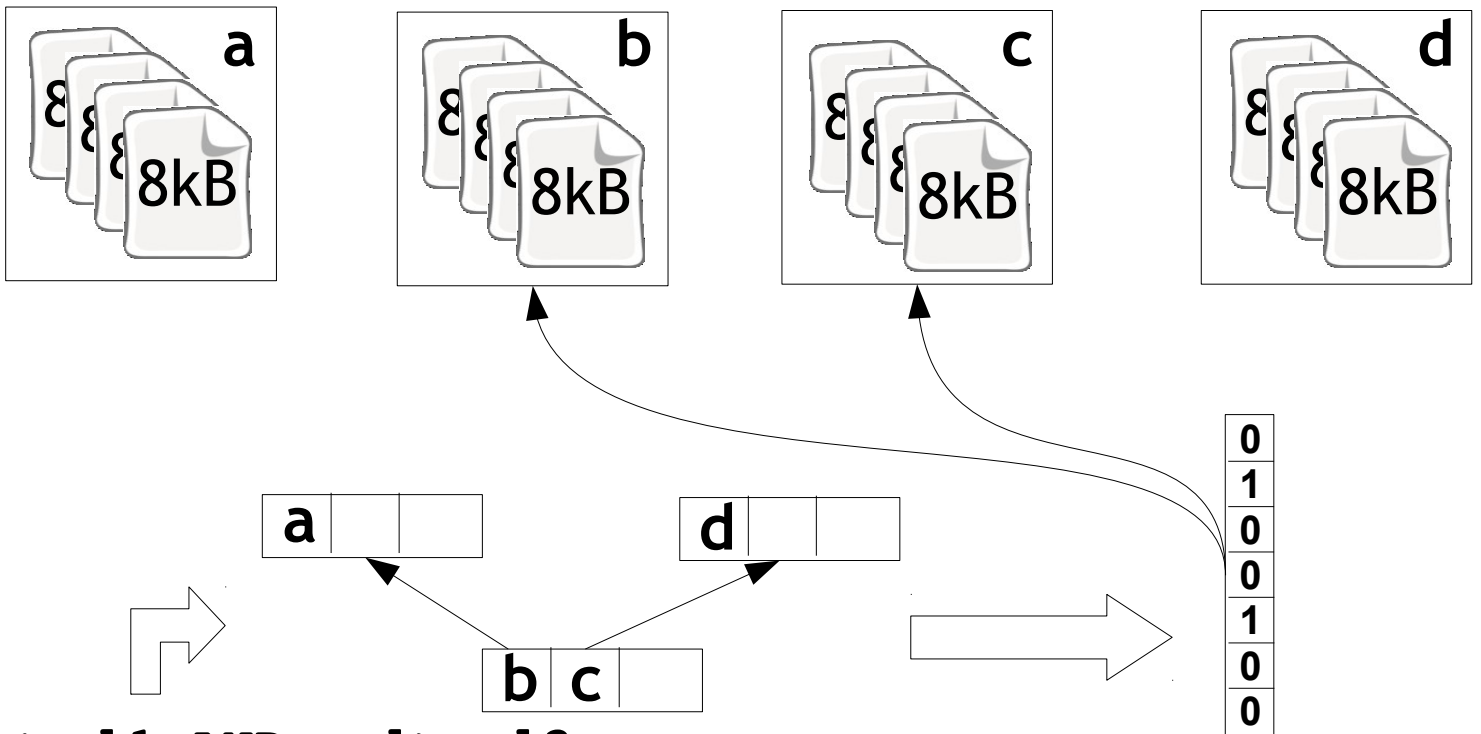





```
...WHERE col<val1 AND col>val2;
```

BitMapIndexScan

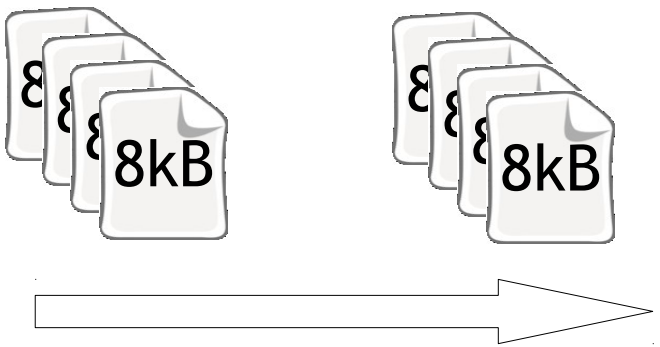
BRIN - scan execution




```
...WHERE col<val1 AND col>val2;
```

BitMapHeapScan

BRIN - scan execution



"ordered" **TidScan**

(recheck cond)

```
...WHERE col<val1 AND col>val2;
```

BRIN - an example of execution plan

```
                                QUERY PLAN
 ---------------------------------------------------------------------------
 -> Bitmap Heap Scan on column  (cost=113.50..26741.01 rows=10000
width=20) (actual time=6.513..3094.020 rows=2499193 loops=1)
     Recheck Cond: column = value
     Rows Removed by Index Recheck: 7500807
     Heap Blocks: lossy=63695
    ->  Bitmap Index Scan on brin_index  (cost=0.00..111.00 rows=10000
width=0) (actual time=6.200..6.200 rows=637440 loops=1)
          Index Cond: column = value
```

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

BRIN support and extensibility

- Two kind of support functions required in the **`OpClass`**:
  - **`minmax`** key values are added following sorting criteria + sorting operators
  - **`inclusion`** key values are added following inclusion criteria + inclusion operators
  - No kNN support currently available!
- **Extensibility**
  - provide support functions + operators to define the **`OpClass`**

`http://www.postgresql.org/docs/9.5/static/brin-extensibility.html`

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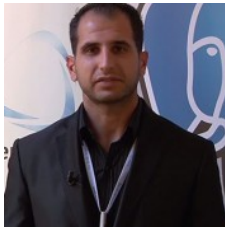
BRIN support for PostGIS

Ronan Dunklau

Julien Rouhaud



me

DALIBO
L'expertise PostgreSQL

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OSGeo
Code Sprint
Paris 2016

https://github.com/dalibo/postgis/tree/for_upstream

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

BRIN support for PostGIS

- Different **`OpClass`** (**`inclusion`** support) for
  - 2D (default), 3D, 4D **`geometry`**
  - **`geography`**
  - **`box2d/box3d`** (cross-operators defined in the **`OpFamily`**)
- Storage datatype: float-precision (such as in GiST)
  - **`gidx`** (3D, 4D **`geometry`**)
  - **`box2df`** (2D **`geometry`**, **`geography`**)
- **`brin_inclusion_add_value()`** has been redefined
- Operators: **`&&`**, **`@`**, **`~`** (2D) - **`&&&`** (3D, 4D)

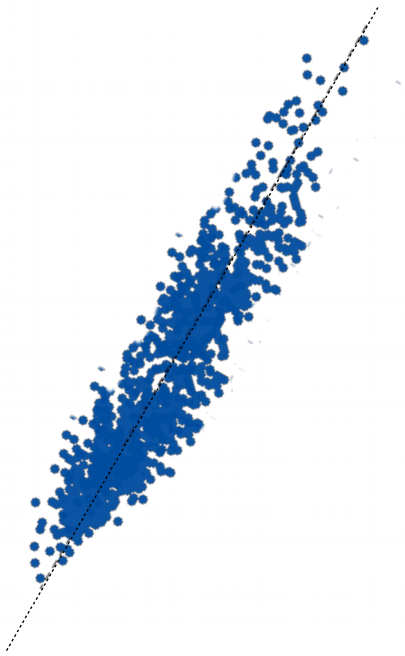
NO kNN SUPPORT!!

Now it's time to test our patch!

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

1st example: "sorted" geometry points

~10M, 3D, SRID=0, distribution range: 0÷100kunits



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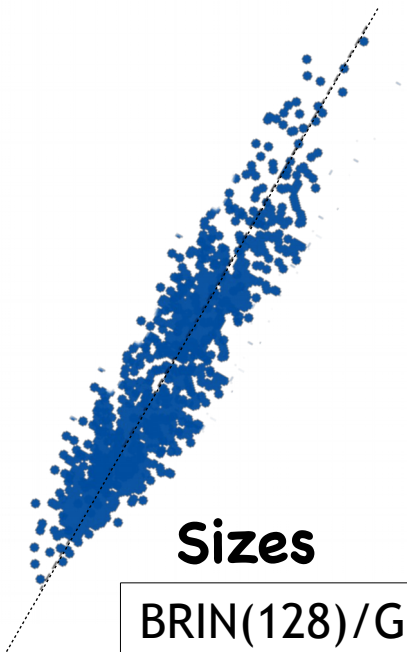
1st example: "sorted" geometry points



~10M, 3D, SRID=0, distribution range: 0÷100kunits

```
=# CREATE INDEX idx_gist ON points USING gist
-# (geom gist_geometry_ops_nd);

=# CREATE INDEX idx_brin_128 ON points USING brin
-# (geom brin_geometry_inclusion_ops_3d);

=# CREATE INDEX idx_brin_10 ON points USING brin
-# (geom brin_geometry_inclusion_ops_3d)
-# WITH (pages_per_range=10);
```

Sizes

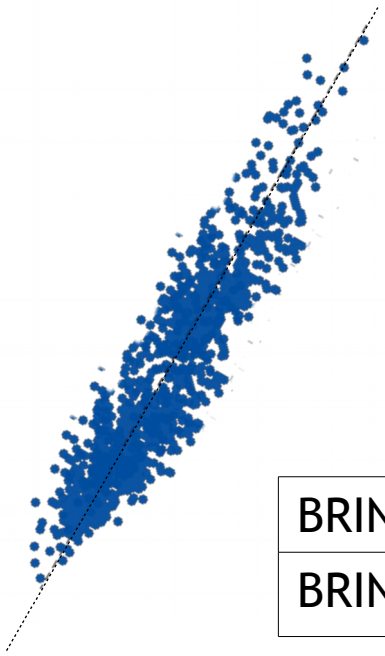
BRIN(128)/GiST	1/2000
BRIN(10)/GiST	1/1000

Building times

BRIN(128)/GiST	1/30
BRIN(10)/GiST	1/20

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

1st example: "sorted" geometry points



~10M, 3D, SRID=0, distribution range: 0÷100kunits

```
=# SELECT * FROM points
-# WHERE 'BOX3D(10. 10. 10., 12., 12., 12.)'::box3d &&& geom;
```

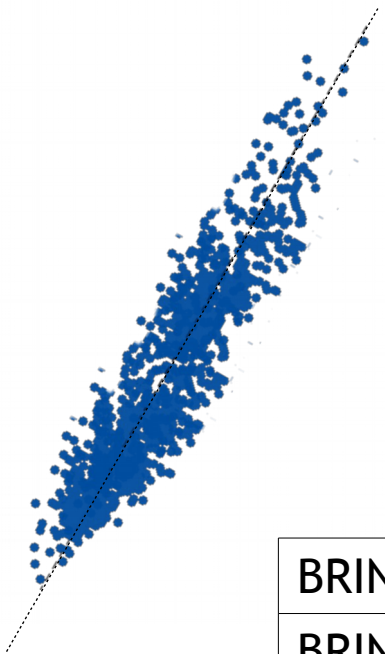
Execution times

BRIN(128)/GiST	50/1
BRIN(10)/GiST	6/1

BRIN(128)/SeqScan	1/60
BRIN(10)/SeqScan	1/350

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

2nd example: "unsorted" geometry points



~10M, 3D, SRID=0, distribution range: 0÷100kunits

```
=# CREATE TABLE unsorted_points AS
-# SELECT * FROM points ORDER BY random();

=# SELECT * FROM unsorted_points
-# WHERE 'BOX3D(10. 10. 10., 12., 12., 12.)'::box3d &&& geom;
```

Execution times

BRIN(128)/GiST	2800/1
BRIN(10)/GiST	400/1

BRIN(128)/SeqScan	1/1
BRIN(10)/SeqScan	1/12

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

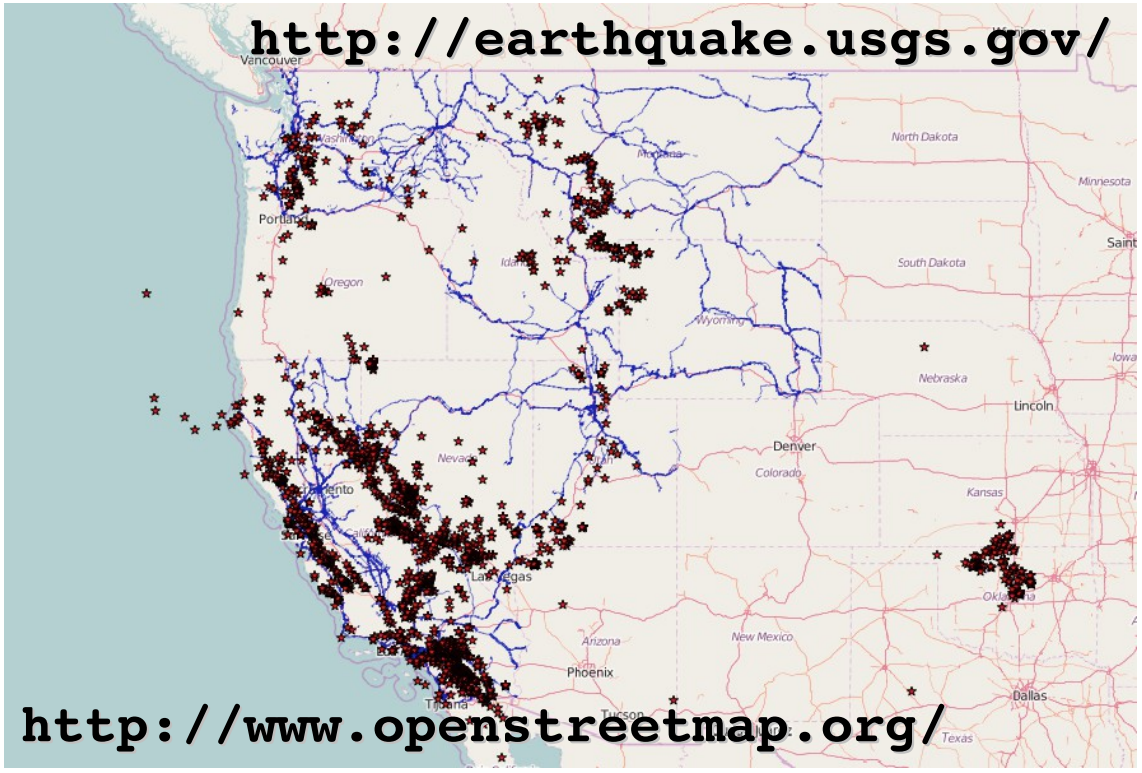
2nd example: "unsorted" geometry points

```
=# CREATE EXTENSION pageinspect;

=# SELECT blknum, value FROM brin_page_items(get_raw_page('idx_brin_128', 2), 'idx_brin_128')
-# LIMIT 5;
 blknum |                                        value
--------+-------------------------------------------------------------------------
      0 | {GIDX( 1.11394846439 1.64980053902 1.11335003376, 99982.2578125 99982.640625
99982.1171875 ) .. f .. f}
    128 | {GIDX( 0.224781364202 0.184096381068 0.798862099648, 99995.859375 99995.171875
99995.0390625 ) .. f .. f}
    256 | {GIDX( 6.25802087784 6.50119876862 6.8031873703, 99993.15625 99993.8203125
99993.2109375 ) .. f .. f}
    384 | {GIDX( 1.9203556776 1.11907613277 1.55043530464, 99995.421875 99995.234375
99995.421875 ) .. f .. f}
    512 | {GIDX( 3.44181084633 3.4120452404 3.41762590408, 99996.3125 99996.7109375 99996.59375
) .. f .. f}
(5 rows)
```


Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

A real case: earthquakes in the USA in 2016



~100k lat/lon WGS84 points
(earthquakes in the world)

~1M SRID 102008 linestrings
(railways in the west side, not Colorado)

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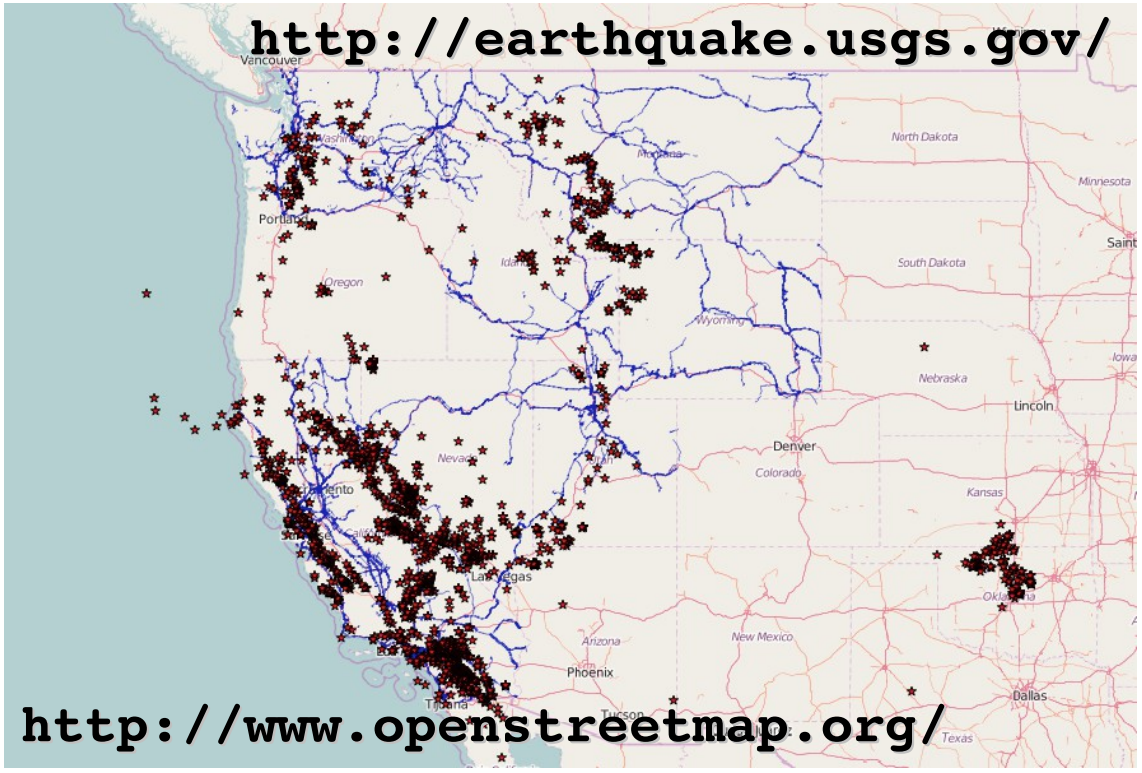
A real case: earthquakes in the USA in 2016



~100k lat/lon WGS84 points (earthquakes in the world)

~1M SRID 102008 linestrings (railways in the west side, not Colorado)

Which railway was close (<10km) to an earthquake epicenter?

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

A real case: earthquakes in the USA in 2016

GiST

```
=# CREATE INDEX idx_rl_gist ON westrailways USING gist
-# (ST_Buffer(GEOGRAPHY(ST_Trasform(geom), 4326), 10000));

=# CREATE INDEX idx_eq_brin ON worldearthquakes USING gist (coord);
```

BRIN

```
=# CREATE INDEX idx_rl_brin ON westrailways USING brin
-# (ST_Buffer(GEOGRAPHY(ST_Trasform(geom), 4326), 10000))
-# WITH (pages_per_range=10);

=# CREATE INDEX idx_eq_brin ON worldearthquakes USING brin (coord)
-# WITH (pages_per_range=10);
```

BRIN/GiST Sizes	~1/100
BRIN/GiST Times	~1/200

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

A real case: earthquakes in the USA in 2016

```
=# WITH us_eq AS (
-#     SELECT coord FROM world
-#     WHERE coord && 'BOX2D(-126.90 49.73, -65.83 24.73)'::box2d
-# ) SELECT * FROM railways r, us_eq u
-#   WHERE ST_Buffer(GEOGRAPHY(ST_Trasform(geom), 4326), 10000) && u.coord;
```

- without indexes: ~60s
- with GiST: ~20ms
- with BRIN: ~400ms

...so, is GIS data "naturally" ordered?

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

It's not a matter of "natural" order...

- both indexes are used: **`bitmapindexscan/bitmapheapscan`**
  - indexes pages has to be read many times!
- the query plan is "complex" - more "recheck" nodes in the plan

```
Recheck Cond: (ST_Buffer(GEOGRAPHY(ST_Trasform(geom), 4326), 10000) && u.coord)
              Rows Removed by Index Recheck: 10546
              Heap Blocks: lossy=512
```

BRIN

```
Recheck Cond: (ST_Buffer(GEOGRAPHY(ST_Trasform(geom), 4326), 10000) && u.coord)
              Rows Removed by Index Recheck: 5424
              Heap Blocks: lossy=42
```

GiST

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

...what about INSERT's?

```
INSERT INTO railways SELECT * FROM colorado_railways;
```

GiST	147ms
BRIN (10)	79ms
BRIN (128)	63ms
No indexes	23ms

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

A really good testbed: LiDAR data

PostgreSQL extension for LiDAR data: **pg_pointcloud**

http://www.slideshare.net/GiuseppeBroccolo/gbroccolo-foss4-geugeodbindex

GiST performances:

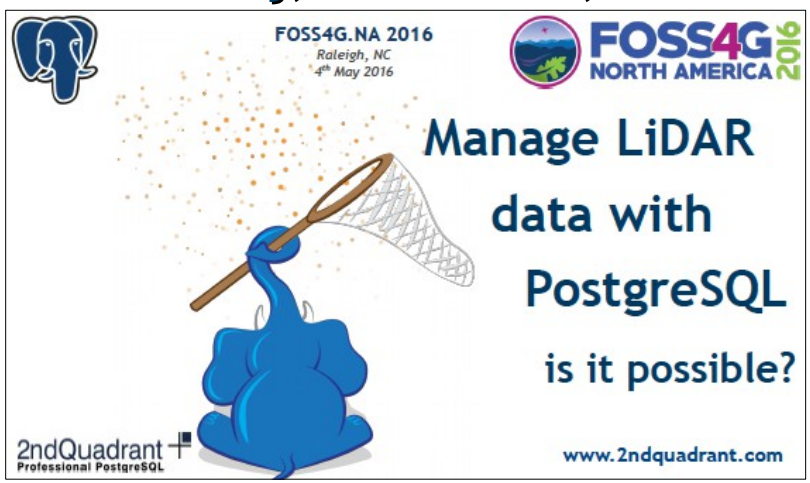
- storage: 1TB RAID1, RAM 16GB, 8 CPU @3.3GHz, PostgreSQL9.3
- index size ~O(table size)
- Index was used:
  - up to ~300M points in bbox inclusion searches
  - up to ~10M points in kNN searches

LiDAR size: ~O($10^9 \div 10^{11}$) → less than 10% can be properly indexed!

Is the patch compatible with `pg_pointcloud`?

1.6TB, ~250G points in ~560M patches

4th May, room 302C, 5:20PM



Here just a summary:

- BRIN/GiST ~O(10MB) not ~O(10GB)
- BRIN/GiST ~O(1h) not ~O(1day)
- bbox inclusion searches:
  - GiST = 20x faster than BRIN
  - BRIN = 200x faster than SeqScan
  - BRIN work better with low selectivity queries
    - All BRIN index pages can be contained in RAM
    - `SELECT`s on more than ~50% of the dataset through BRIN scan

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

Conclusions

- BRINs can be successfully used in geo DB based on PostgreSQL
  - totally support PostGIS datatype
    - A patch almost ready for the next PostGIS release (2.3.0)
  - easier indexes maintenance, low indexing time, low impact on concurrent **`INSERT`**s
  - less specific than GiST...but not to much!
- Really small indexes!
  - GiST performances drop as well as it cannot be totally contained in RAM
  - BRIN can be successfully used in LiDAR dataset, at least for bbox inclusion searches

Giuseppe Broccolo - giuseppe.broccolo@2ndquadrant.it

Special thanks to...

- Julien Rouhaud
- Ronan Dunklau

- Alvaro Herrera
- Emre Hesegeli

- ...and to 2ndQuadrant!

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