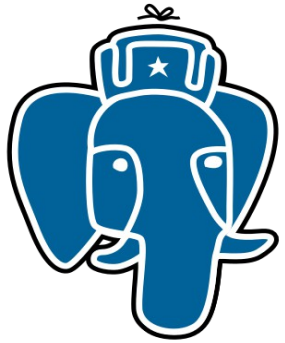
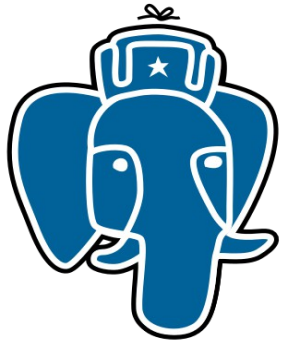


Schema-less PostgreSQL

Current and Future

Олег Бартунов (ГАИШ МГУ)



Oleg Bartunov, Teodor Sigaev

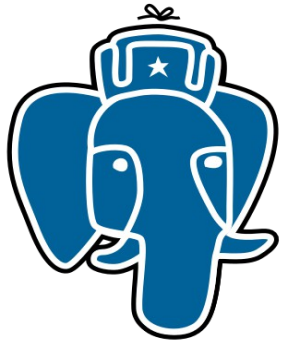
- Locale support
- Extendability (indexing)
  - GiST (KNN), GIN, SP-GiST
- Full Text Search (FTS)
- Jsonb, VODKA
- Extensions:
  - intarray
  - pg_trgm
  - ltree
  - hstore
  - plantuner

https://www.facebook.com/oleg.bartunov
obartunov@gmail.com, teodor@sigaev.ru
https://www.facebook.com/groups/postgresql/

Alexander Korotkov

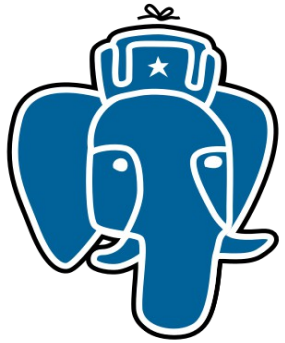
- Indexed regexp search
- GIN compression & fast scan
- Fast GiST build
- Range types indexing
- Split for GiST

aekorotkov@gmail.com



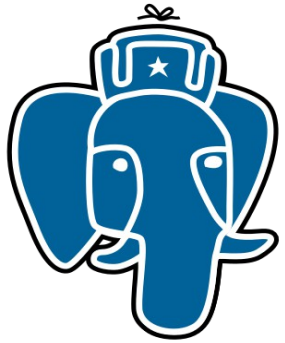
Agenda

- Semi-structured data in PostgreSQL
- Introduction to jsonb indexing
- Jsquery - Jsonb Query Language
- Exercises on jsonb GIN opclasses with Jsquery support
- VODKA access method



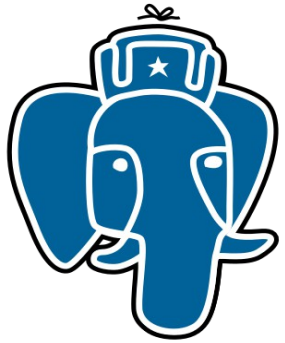
Слабо-структурированные данные

- Слабо-структурированные данные возникают от лени :)
- Агрегирование структурированных данных приводит к слабо-структурированным данным (разреженная матрица)
- Все слабо-структурированные данные можно реализовать стандартными способами RDBMS
  - Неудобно, проблемы с производительностью
- json — жупел слабо-структурированных данных
- Реальная проблема — это schema-less данные
  - Реляционные СУБД трудно переживают изменение схемы
  - Key-value (NoSQL) хранилища таких проблем не имеют



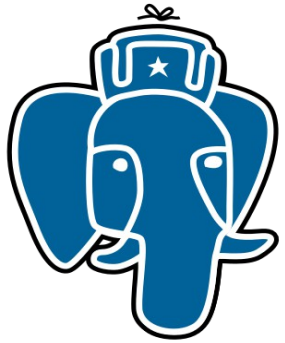
Relational Databases

- Реляционные СУБД — интеграционные
  - Все приложения общаются через СУБД
  - SQL — универсальный язык работы с данными
  - Все изменения в СУБД доступны всем
  - Изменения схемы очень затратны, медл. релизы
  - Рассчитаны на интерактивную работу
    - Интересны агрегаты, а не сами данные, нужен SQL
    - SQL отслеживает транзакционность, ограничения целостности... вместо человека



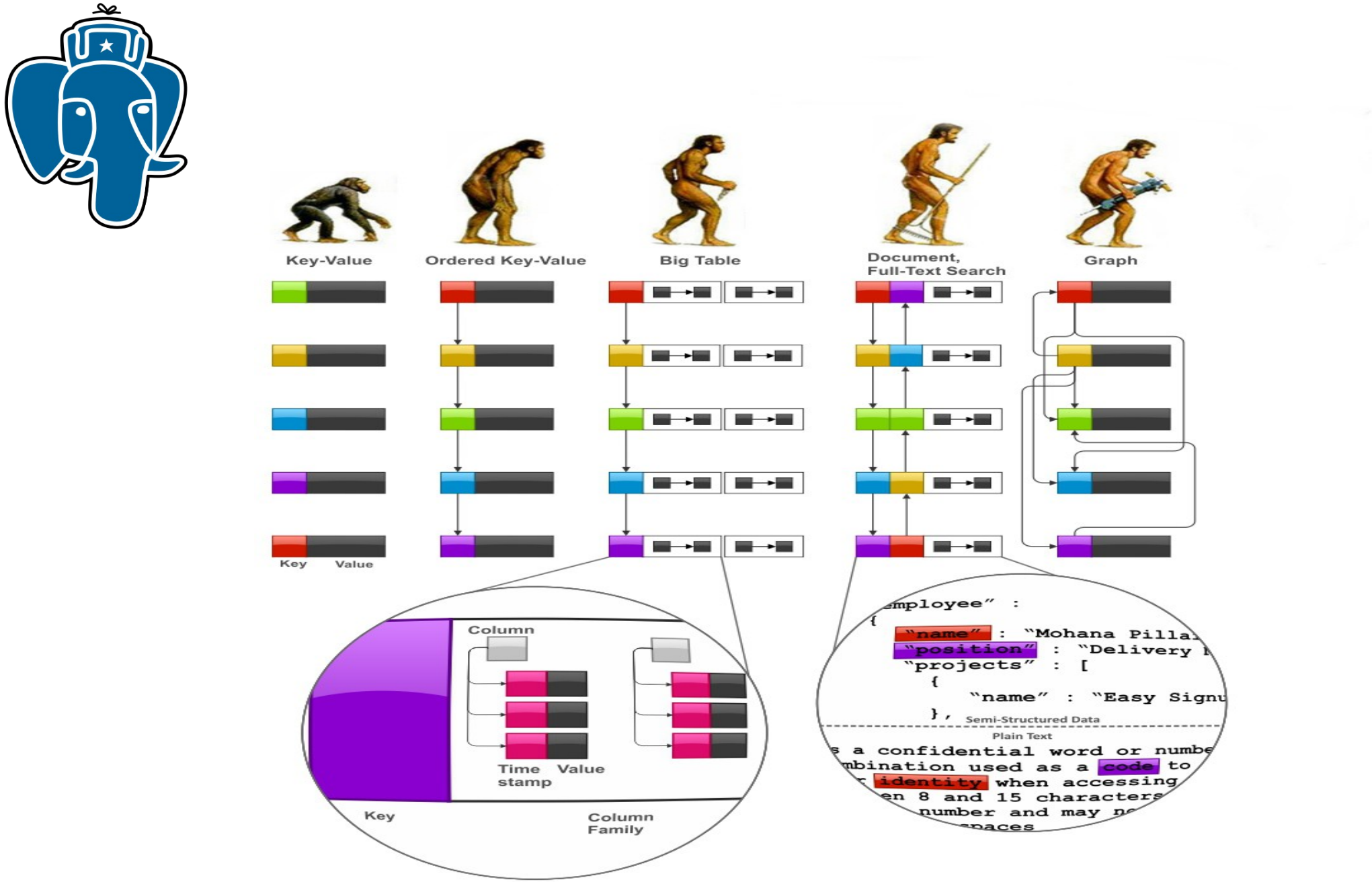
NoSQL (концептуальные предпосылки)

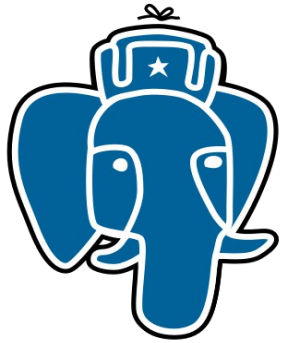
- Сервисная архитектура изменила подход к СУБД
  - Приложение состоит из сервисов, SQL->HTTP
  - Сервисам не нужна одна монолитная СУБД
  - Часто достаточно простых key-value СУБД
  - Схема меняется «на ходу», быстрые релизы
  - ACID → BASE
  - Сервисы — это программы, которые могут сами заниматься агрегированием
  - Сервисы могут сами следить за целостностью данных
- Много данных, аналитика, большое кол-во одновременных запросов
  - Распределенность - кластеры дешевых shared-nothing машин
- NoSQL —горизонтальная масштабируемость и производительность



NoSQL

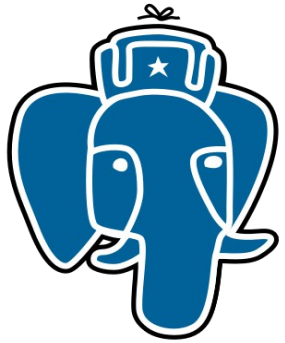
- Key-value databases
  - Ordered k-v для поддержки диапазонов
- Column family (column-oriented) stores
  - Big Table — value имеет структуру:
    - column families, columns, and timestamped versions (maps-of maps-of maps)
- Document databases
  - Value - произвольная сложность, индексы
    - Имена полей, FTS — значение полей
- Graph databases — эволюция ordered-kv


Key-Value
Ordered Key-Value
Big Table
Document,
Full-Text Search
Graph
Key
Value
Column
Time stamp
Value
Key
Column Family
"name" : "Mohana Pilla
"position" : "Delivery
"projects" : [
{
"name" : "Easy Signu
},
Semi-Structured Data
Plain Text
a confidential word or numbe
bination used as a code to
identity when accessing
en 8 and 15 characters
number and may n
paces



Челлендж !

- Полноценная работа со слабо-структурированными данными в реляционной СУБД
  - Хранение (тип данных для хранение key-value данных)
  - Поиск (операторы и функции)
  - Производительность (бинарное хранилище, индексы)



Introduction to hstore

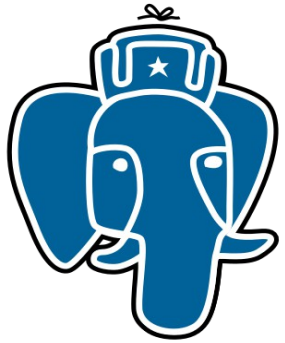
- Hstore — key/value storage (inspired by perl hash)

```
'a=>1, b=>2'::hstore
```

  - Key, value — strings
  - Get value for a key: hstore -> text
  - Operators with indexing support (GiST, GIN)

    Check for key: hstore ? text
    Contains: hstore @> hstore

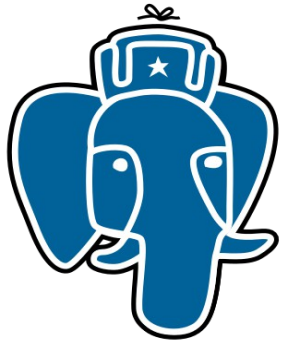
  - check documentations for more
  - Functions for hstore manipulations (akeys, avals, skeys, svals, each,.....)



History of hstore development

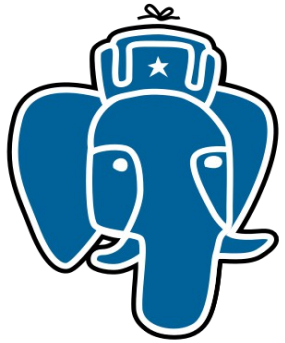
- May 16, 2003 — first version of hstore

```
Date: Fri, 16 May 2003 22:56:14 +0400
From: Teodor Sigaev <teodor@sigaev.ru>
To: Oleg Bartunov <oleg@sai.msu.su>, Alexey Slynko <slynko@tronet.ru>
Cc: E.Rodichev <er@sai.msu.su>
Subject: hash type (hstore)

Готова первайа версия:
zeus:~teodor/hstore.tgz

README написать не успел, поэтому здесь:
1 i/o типа hstore
2 операция hstore->text - извлечение значения по ключу text
select 'a=>q, b=>g'->'a';
 ?
------
 q

3 isexists(hstore), isdefined(hstore), delete(hstore,text) - полный перловый аналог
4 hstore || hstore - конкатенация, аналог в перле %a=( %b, %c );
5 text=>text - возвращает hstore
select 'a'=>'b';
 ?column?
----------
 "a"=>"b"


Все примеры есть в sql/hstore.sql
```



Introduction to hstore

- Hstore benefits
  - In provides a flexible model for storing a semi-structured data in relational database
  - hstore has binary storage
- Hstore drawbacks
  - Too simple model !
    Hstore key-value model doesn't supports tree-like structures as json (introduced in 2006, 3 years after hstore)
- Json — popular and standartized (ECMA-404 The JSON Data Interchange Standard, JSON RFC-7159)
- Json — PostgreSQL 9.2, textual storage

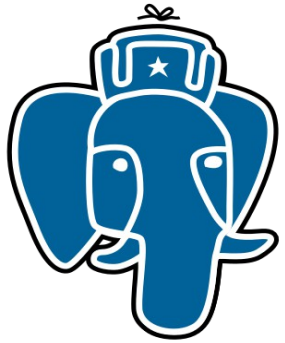


Hstore vs Json

- hstore явно быстрее json даже на простых данных

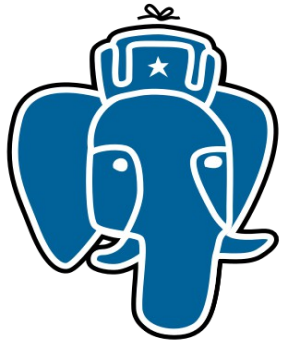
```
CREATE TABLE hstore_test AS (SELECT
'a=>1, b=>2, c=>3, d=>4, e=>5'::hstore AS v
FROM generate_series(1,1000000));

CREATE TABLE json_test AS (SELECT
'{"a":1, "b":2, "c":3, "d":4, "e":5}'::json AS v
FROM generate_series(1,1000000));
```

```
SELECT sum((v->'a')::text::int) FROM json_test;
851.012 ms

SELECT sum((v->'a')::int) FROM hstore_test;
330.027 ms
```



Hstore vs Json

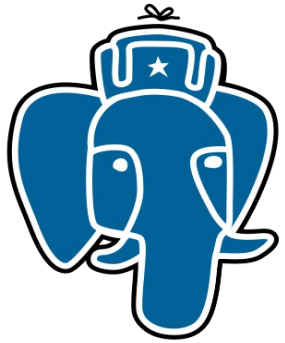
- PostgreSQL already has json since 9.2, which supports document-based model, but
  - It's slow, since it has no binary representation and needs to be parsed every time
  - Hstore is fast, thanks to binary representation and index support
  - It's possible to convert hstore to json and vice versa, but current hstore is limited to key-value
  - Need hstore with document-based model. Share it's binary representation with json !



History of hstore development

- May 16, 2003 - first (unpublished) version of hstore for PostgreSQL 7.3
- Dec, 05, 2006 - hstore is a part of PostgreSQL 8.2

  (thanks, Hubert Depesz Lubaczewski!)
- May 23, 2007 - GIN index for hstore, PostgreSQL 8.3
- Sep, 20, 2010 - Andrew Gierth improved hstore, PostgreSQL 9.0



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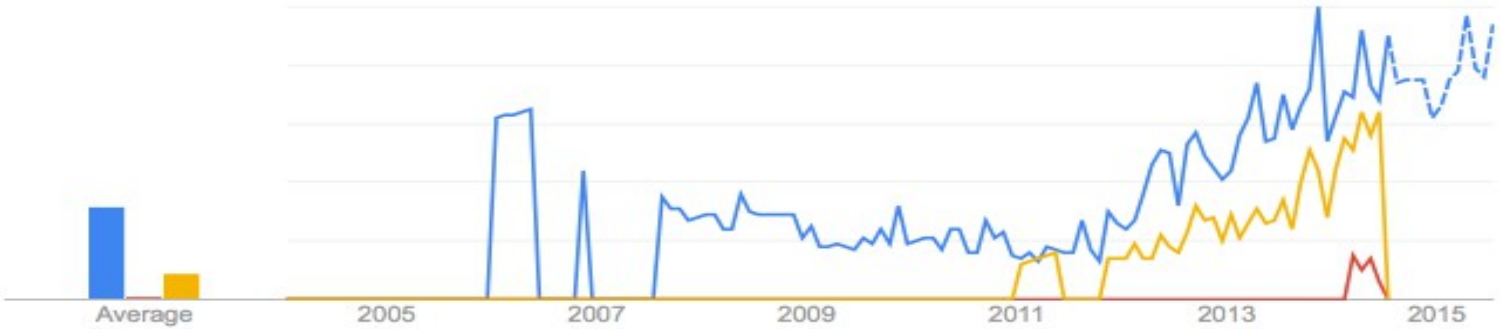
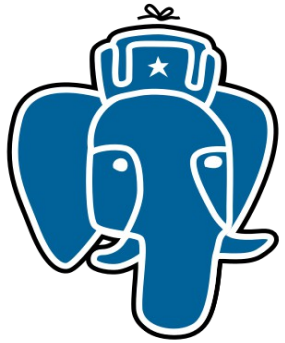


Regional interest

hstore | jsonb | json postgresql

Region | City

Australia	100
United States	15



Nested hstore

abstract

Oleg Bartunov <obartunov@gmail.com> 12/18/12

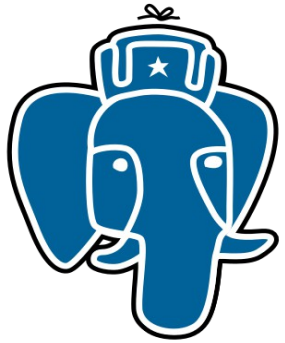
to Teodor

Поправь, дополни.

Title: One step forward true json data type. Nested hstore with array support.

We present a prototype of nested hstore data type with array support. We consider the new hstore as a step forward true json data type.

Recently, PostgreSQL got json data type, which basically is a string storage with validity checking for stored values and some related functions. To be a real data type, it has to have a binary representation, which could be a big project if started from scratch. Hstore is a popular data type, we developed years ago to facilitate working with semi-structured data in PostgreSQL. Our idea is to extend hstore to be nested (value can be hstore) data type and add support of arrays, so its binary representation can be shared with json. We present a working prototype of a new hstore data type and discuss some design and implementation issues.

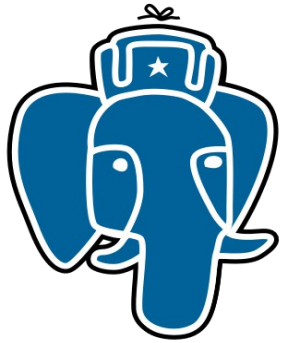


Nested hstore & jsonb

- Nested hstore был представлен на PGCon-2013, Оттава, Канада (24 мая) — спасибо Engine Yard за поддержку !

  One step forward true json data type.Nested hstore with arrays support

- Бинарное хранилище для вложенных структур было представлено на PGCon Europe — 2013, Дублин, Ирландия (29 октября)
  Binary storage for nested data structuresand application to hstore data type
- В ноябре бинарное хранилище было стандартизовано
  - nested hstore и jsonb — разные интерфейсы доступа к хранилищу
- В начале января Andrew Dunstan начинает активно работать по jsonb
  - бинарное хранилище и основной функционал перемещается в ядро постгреса

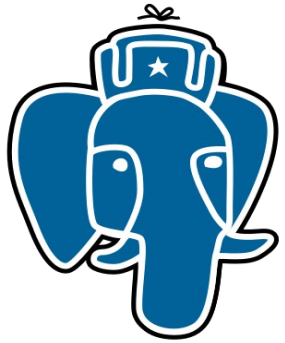


Nested hstore & jsonb

- В феврале-марте подключается Peter Geoghegan, мы принимаем решение оставить hstore как есть, чтобы избежать проблем с совместимостью (Nested hstore patch for 9.3).
- 23 марта Andrew Dunstan закомитил jsonb в ветку 9.4 !
  pgsql: Introduce jsonb, a structured format for storing json.

  Introduce jsonb, a structured format for storing json.

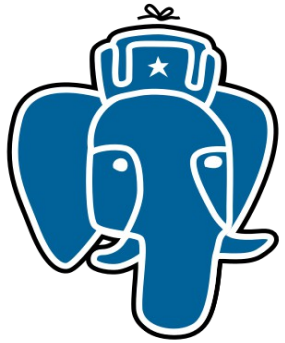
  The new format accepts exactly the same data as the json type. However, it is stored in a format that does not require reparsing the orgiginal text in order to process it, making it much more suitable for indexing and other operations. Insignificant whitespace is discarded, and the order of object keys is not preserved. Neither are duplicate object keys kept - the later value for a given key is the only one stored.



Jsonb vs Json

```
SELECT '{"c":0,  "a":2,"a":1}'::json, '{"c":0,   "a":2,"a":1}'::jsonb;
         json           |      jsonb
------------------------+------------------
 {"c":0,  "a":2,"a":1} | {"a": 1, "c": 0}
(1 row)
```

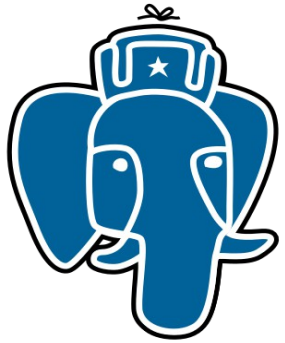
- json: textual storage «as is»
- jsonb: no whitespaces
- jsonb: no duplicate keys, last key win
- jsonb: keys are sorted



Jsonb vs Json

- Data
  - 1,252,973 Delicious bookmarks
- Server
  - MBA, 8 GB RAM, 256 GB SSD
- Test
  - Input performance - copy data to table
  - Access performance - get value by key
  - Search performance contains @> operator

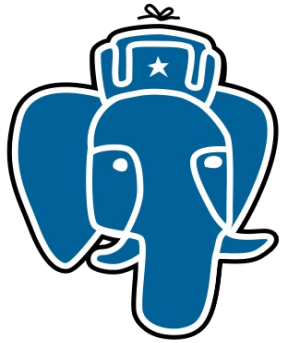

```
{
    "author": "mcasas1",
    "comments": "http://delicious.com/url/b5b3cbf9a9176fe43c27d7b4af94a422",
    "guidislink": false,
    "id": "http://delicious.com/url/b5b3cbf9a9176fe43c27d7b4af94a422#mcasas1",
    "link": "http://www.theatermania.com/broadway/",
    "links": [
        {
            "href": "http://www.theatermania.com/broadway/",
            "rel": "alternate",
            "type": "text/html"
        }
    ],
    "source": {},
    "tags": [
        {
            "label": null,
            "scheme": "http://delicious.com/mcasas1/",
            "term": "NYC"
        }
    ],
    "title": "TheaterMania",
    "title_detail": {
        "base": "http://feeds.delicious.com/v2/rss/recent?min=1&count=100",
        "language": null,
        "type": "text/plain",
        "value": "TheaterMania"
    },
    "updated": "Tue, 08 Sep 2009 23:28:55 +0000",
    "wfw_commentrss": "http://feeds.delicious.com/v2/rss/url/b5b3cbf9a9176fe43c27d7b4af94a422"
}
```



Jsonb vs Json

- Data
  - 1,252,973 bookmarks from Delicious in json format (js)
  - The same bookmarks in jsonb format (jb)
  - The same bookmarks as text (tx)

```
=# \dt+
                    List of relations
 Schema | Name | Type  |  Owner   |  Size   | Description
--------+------+-------+----------+---------+-------------
 public | jb   | table | postgres | 1374 MB | overhead is < 4%
 public | js   | table | postgres | 1322 MB |
 public | tx   | table | postgres | 1322 MB |
```

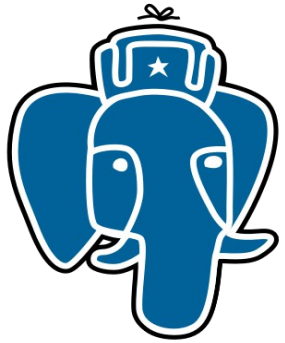


Jsonb vs Json

- Input performance (parser)
  Copy data (1,252,973 rows) as text, json,jsonb

```
copy tt from  '/path/to/test.dump'
```

Text: 34 s - as is
Json: 37 s - json validation
Jsonb: 43 s - json validation, binary storage

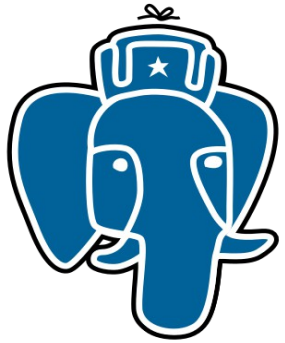


Jsonb vs Json (binary storage)

- Access performance — get value by key
  - Base: SELECT js FROM js;
  - Jsonb: SELECT j->>'updated' FROM jb;
  - Json: SELECT j->>'updated' FROM js;

Base:	0.6 s	
Jsonb:	1 s	0.4
Json:	9.6 s	9

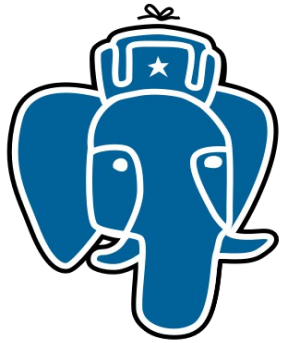
Jsonb ~ 20X faster Json



Jsonb vs Json

```
EXPLAIN ANALYZE SELECt count(*) FROM js WHERE js #>>'{tags,0,term}' = 'NYC';
                                                     QUERY PLAN
-------------------------------------------------------------------------------------------------------------------
 Aggregate  (cost=187812.38..187812.39 rows=1 width=0)
(actual time=10054.602..10054.602 rows=1 loops=1)
   ->  Seq Scan on js  (cost=0.00..187796.88 rows=6201 width=0)
(actual time=0.030..10054.426 rows=123 loops=1)
         Filter: ((js #>> '{tags,0,term}'::text[]) = 'NYC'::text)
         Rows Removed by Filter: 1252850
 Planning time: 0.078 ms
 Execution runtime: 10054.635 ms
(6 rows)
```

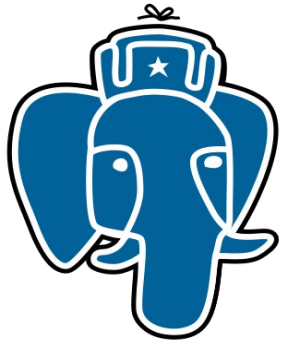
Json: no contains @> operator,
search first array element



Jsonb vs Json (binary storage)

```
EXPLAIN ANALYZE SELECT count(*) FROM jb WHERE jb @> '{"tags":[{"term":"NYC"}]}'::jsonb;
                                                      QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------
 Aggregate  (cost=191521.30..191521.31 rows=1 width=0)
(actual time=1263.201..1263.201 rows=1 loops=1)
   ->  Seq Scan on jb  (cost=0.00..191518.16 rows=1253 width=0)
 (actual time=0.007..1263.065 rows=285 loops=1)
         Filter: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
         Rows Removed by Filter: 1252688
 Planning time: 0.065 ms
 Execution runtime: 1263.225 ms          Execution runtime: 10054.635 ms
(6 rows)
```

Jsonb ~ 10X faster Json

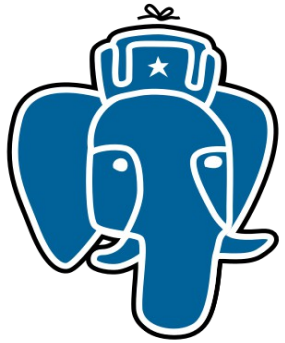


Jsonb vs Json (GIN: key && value)

CREATE INDEX gin_jb_idx ON jb USING gin(jb);

```
EXPLAIN ANALYZE SELECT count(*) FROM jb WHERE jb @> '{"tags":[{"term":"NYC"}]}'::jsonb;
                                                        QUERY PLAN
-----------------------------------------------------------------------------------------------------------
 Aggregate  (cost=4772.72..4772.73 rows=1 width=0)
(actual time=8.486..8.486 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb  (cost=73.71..4769.59 rows=1253 width=0)
(actual time=8.049..8.462 rows=285 loops=1)
         Recheck Cond: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on gin_jb_idx  (cost=0.00..73.40 rows=1253 width=0)
(actual time=8.014..8.014 rows=285 loops=1)
               Index Cond: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
 Planning time: 0.115 ms
 Execution runtime: 8.515 ms           Execution runtime: 10054.635 ms
(8 rows)
```

Jsonb ~ 150X faster Json

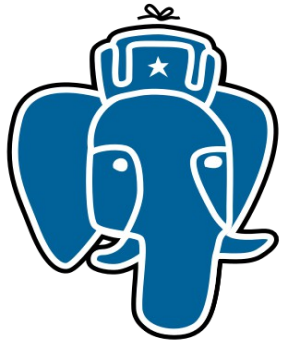


Jsonb vs Json (GIN: hash path.value)

CREATE INDEX gin_jb_path_idx ON jb USING gin(jb jsonb_path_ops);

```
EXPLAIN ANALYZE SELECT count(*) FROM jb WHERE jb @> '{"tags":[{"term":"NYC"}]}'::jsonb;
                                                        QUERY PLAN
-----------------------------------------------------------------------------------------------------------
 Aggregate  (cost=4732.72..4732.73 rows=1 width=0)
(actual time=0.644..0.644 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb  (cost=33.71..4729.59 rows=1253 width=0)
(actual time=0.102..0.620 rows=285 loops=1)
         Recheck Cond: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on gin_jb_path_idx
(cost=0.00..33.40 rows=1253 width=0) (actual time=0.062..0.062 rows=285 loops=1)
               Index Cond: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
 Planning time: 0.056 ms
 Execution runtime: 0.668 ms       Execution runtime: 10054.635 ms
(8 rows)
```

Jsonb ~ 1800X faster Json



MongoDB 2.6.0

- Load data - ~13 min **SLOW !** **Jsonb 43 s**

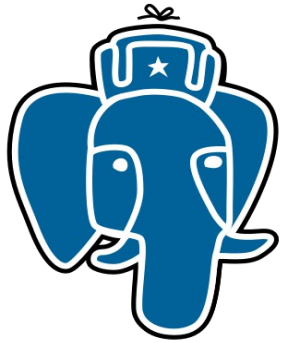
```
mongoimport --host localhost -c js --type json < delicious-rss-1250k
2014-04-08T22:47:10.014+0400                    3700    1233/second
...
2014-04-08T23:00:36.050+0400                    1252000 1547/second
2014-04-08T23:00:36.565+0400 check 9 1252973
2014-04-08T23:00:36.566+0400 imported 1252973 objects
```

- Search - ~ 1s (seqscan) **THE SAME**

```
db.js.find({tags: {$elemMatch:{ term: "NYC"}}}).count()
285
-- 980 ms
```

- Search - ~ 1ms (indexscan) **Jsonb 0.7ms**

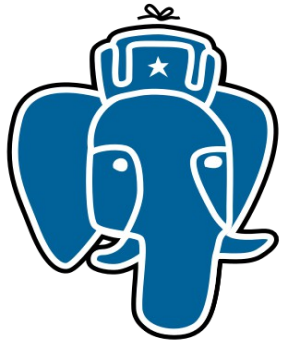
```
db.js.ensureIndex( {"tags.term" : 1} )
db.js.find({tags: {$elemMatch:{ term: "NYC"}}}).
```



Summary: PostgreSQL 9.4 vs Mongo 2.6.0

- Operator contains @>
  - json : 10 s seqscan
  - jsonb : 8.5 ms GIN jsonb_ops
  - **jsonb : 0.7 ms GIN jsonb_path_ops**
  - mongo : 1.0 ms btree index
- Index size
  - jsonb_ops - 636 Mb (no compression, 815Mb)
    jsonb_path_ops - 295 Mb
  - jsonb_path_ops (tags) - 44 Mb USING gin((jb->'tags') jsonb_path_ops
  - mongo (tags) - 387 Mb
    mongo (tags.term) - 100 Mb
- Table size
  - postgres : 1.3Gb
  - mongo : 1.8Gb
- Input performance:
  - Text : 34 s
  - Json : 37 s
  - Jsonb : 43 s
  - mongo : 13 m

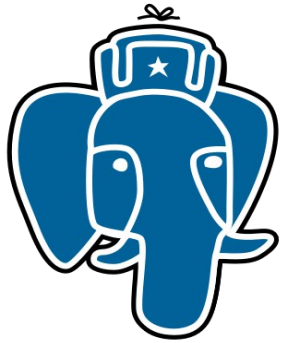
Engine Yard™



Jsonb (Apr, 2014)

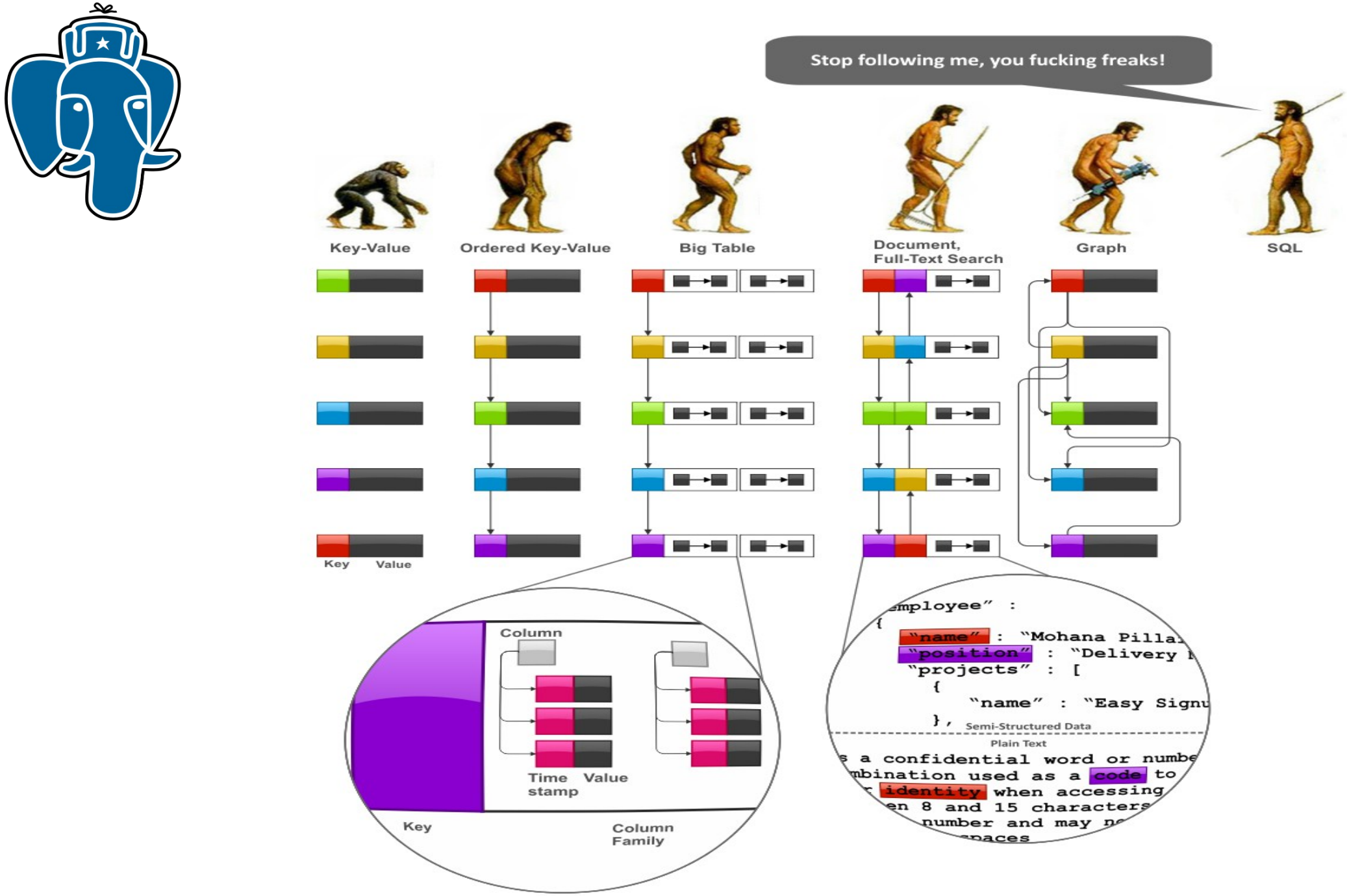
- Документация
  - JSON Types, JSON Functions and Operators
- Осталось портировать много функциональности из nested hstore
  - Это можно сделать расширением
- Нужен язык запросов
- Очень большая работа над структурными запросами
  - «Хочется купить что-нибудь красное» - women oriented query (+)
  - Проект VODKA — новый метод доступа вместо GIN

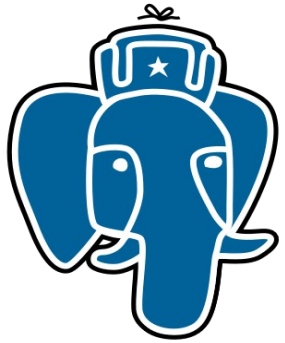
    CREATE INDEX … USING VODKA !
- Реализация <,>,&& … для значений



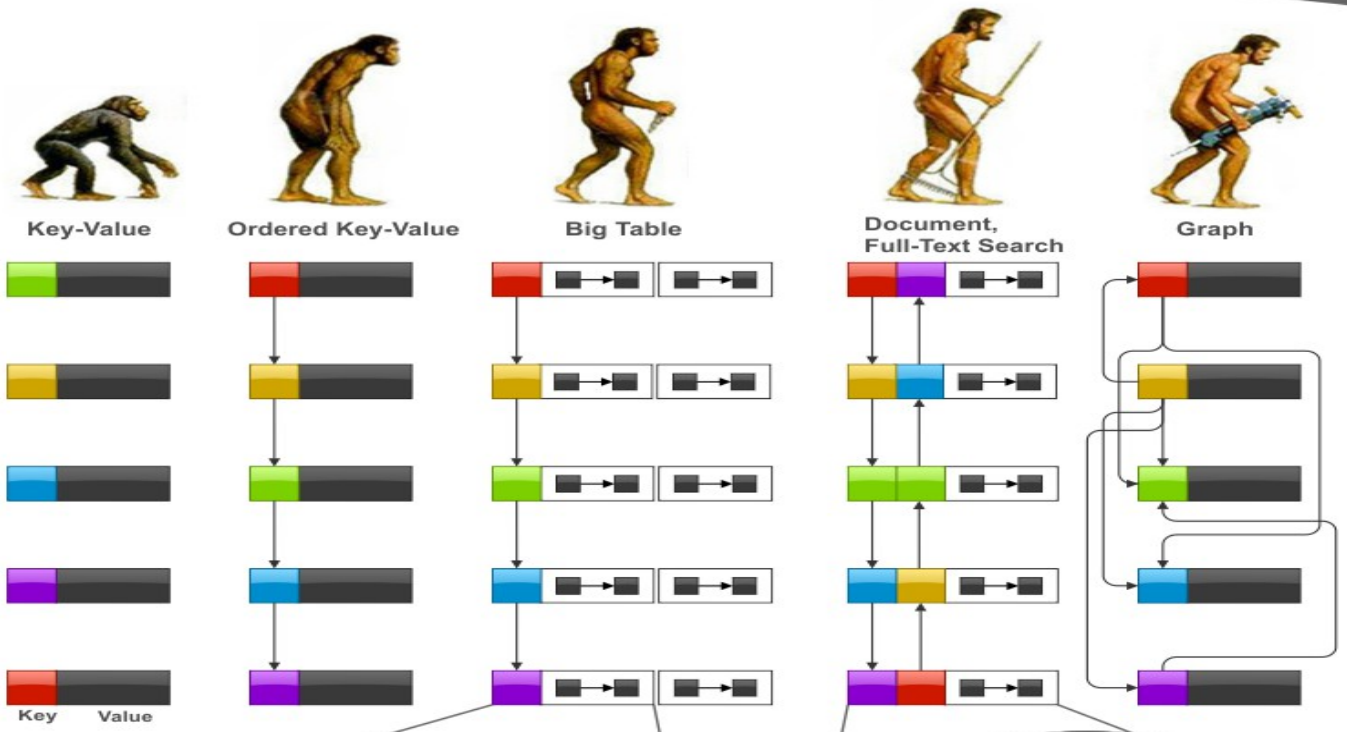
NoSQL vs Relational

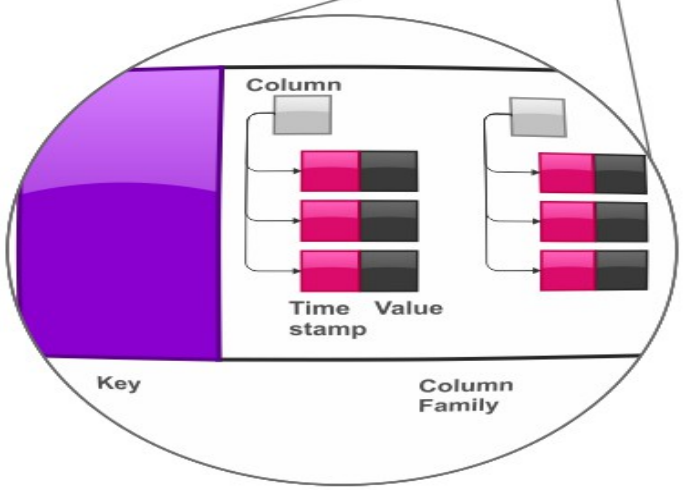
- PostgreSQL 9.4+ — открытая реляционная СУБД с сильной поддержкой слабо-структурированных данных
  - Все плюсы реляционной модели
  - Надежность и целостность данных
  - нормальный json с бинарным хранением и индексами
  - производительность не хуже MongoDB
  - Зачем использовать NoSQL !?
    - 0.1% проектов действительно нуждаются в NoSQL масштабируемости
    - NoSQL хорош для хранения несущественных данных — cache

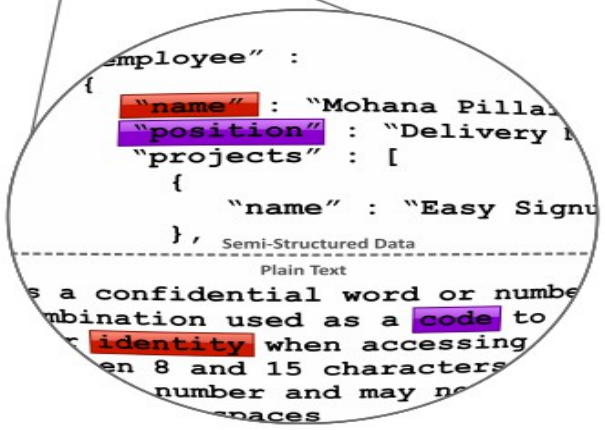

Stop following me, you fucking freaks!
Key-Value
Ordered Key-Value
Big Table
Document,
Full-Text Search
Graph
SQL
Key
Value
Column
Time stamp
Value
Key
Column Family
"name" : "Mohana Pilla
"position" : "Delivery
"projects" : [
{
"name" : "Easy Signu
},
Semi-Structured Data
Plain Text
a confidential word or numbe
mbination used as a code to
identity when accessing
en 8 and 15 characters
number and may n
paces

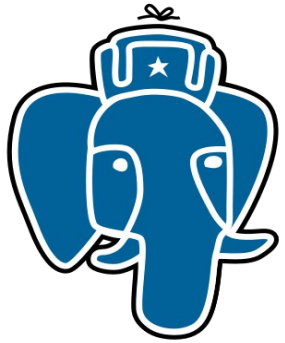



Stop following me, you fucking freaks!


Key-Value
Ordered Key-Value
Big Table
Document,
Full-Text Search
Graph
Key
Value

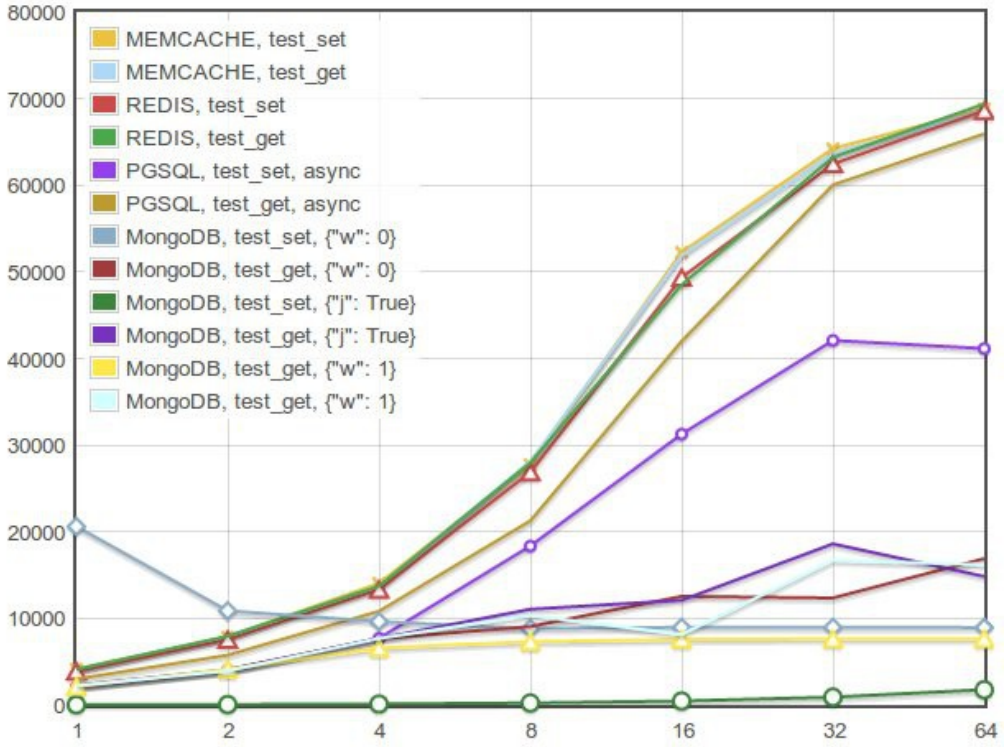

Column
Time stamp
Value
Key
Column Family


"name" : "Mohana Pilla
"position" : "Delivery
"projects" : [
{
"name" : "Easy Signu
},
Semi-Structured Data
Plain Text
a confidential word or numbe
bination used as a code to
identity when accessing
en 8 and 15 characters
number and may n



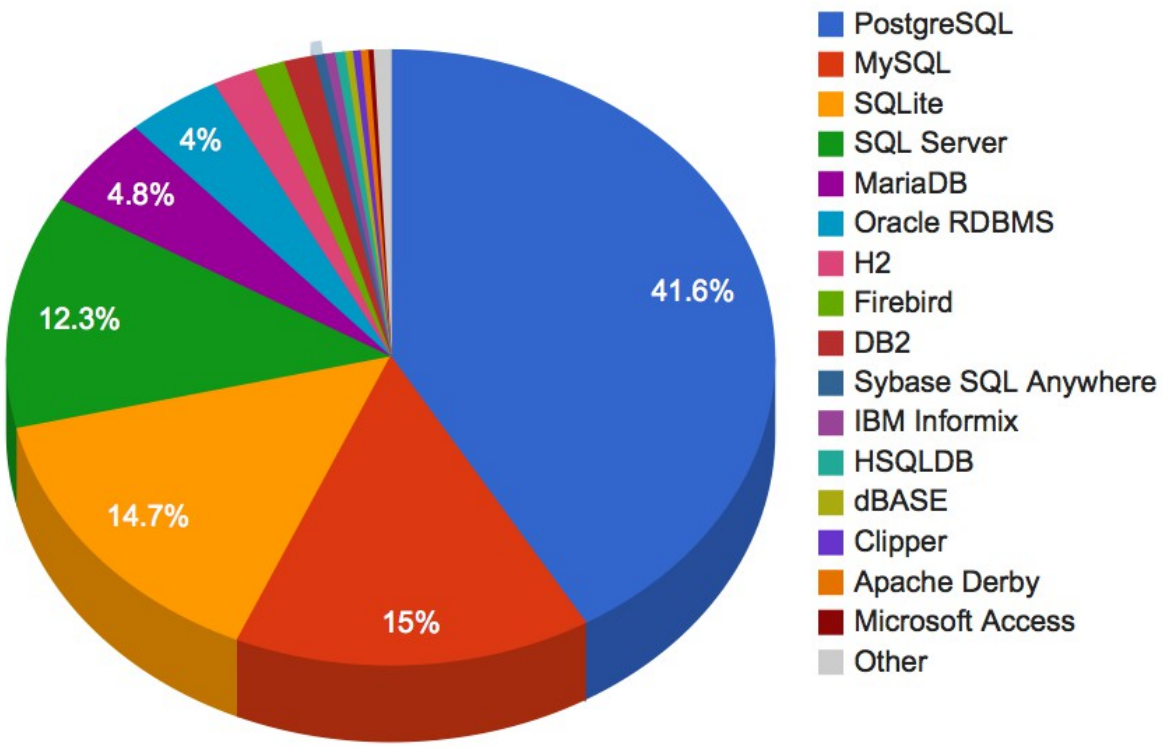
NoSQL vs Relatonal

4-core HT+ server, 1 client with 1..64 python scripts
async → synchronous_commit = off, json documents
data fits in memory

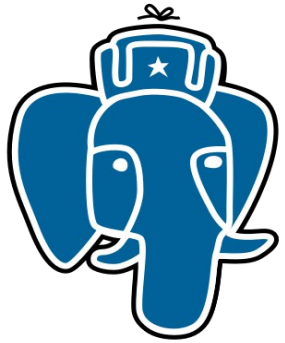


1 Server with 1 to 64 clients, Client(s) and server on separate host
minimum data size: 1188, max size: 2601, average size: 1874

PostgreSQL popularity - 2014



http://www.databasefriends.co/2014/03/favorite-relational-database.html

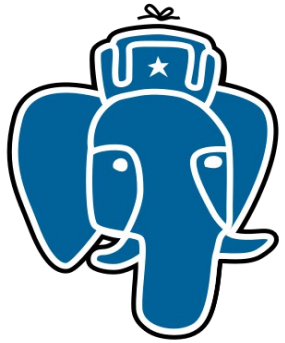


PostgreSQL popularity - 2014

http://db-engines.com/en/ranking

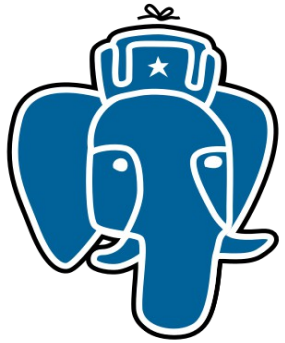
216 systems in ranking, March 2014

Rank	Last Month	DBMS	Database Model	Score	Changes
1.	1.	**Oracle**	**Relational DBMS**	**1491.80**	**-8.43**
2.	2.	**MySQL**	**Relational DBMS**	**1290.21**	**+1.83**
3.	3.	**Microsoft SQL Server**	**Relational DBMS**	**1205.28**	**-8.99**
4.	4.	**PostgreSQL**	**Relational DBMS**	**235.06**	**+4.61**
5.	5.	**MongoDB**	**Document store**	**199.99**	**+4.81**
6.	6.	**DB2**	**Relational DBMS**	**187.32**	**-1.14**
7.	7.	**Microsoft Access**	**Relational DBMS**	**146.48**	**-6.40**
8.	8.	**SQLite**	**Relational DBMS**	**92.98**	**-0.03**
9.	9.	**Sybase ASE**	**Relational DBMS**	**81.55**	**-6.33**
10.	10.	**Cassandra**	**Wide column store**	**78.09**	**-2.23**
11.	11.	Teradata	Relational DBMS	62.63	-1.18
12.	12.	Solr	Search engine	61.14	-1.56
13.	13.	Redis	Key-value store	53.46	-2.36
14.	14.	FileMaker	Relational DBMS	52.91	+1.01
15.	15.	Informix	Relational DBMS	37.20	+1.52
16.	16.	HBase	Wide column store	35.14	-0.01
17.	17.	Memcached	Key-value store	32.90	-1.83
18.	18.	Hive	Relational DBMS	30.21	+2.29
19.	↑ 20.	Elasticsearch	Search engine	26.17	+2.79
20.	↓ 19.	CouchDB	Document store	22.86	-0.57
21.	21.	Splunk	Search engine	22.43	+1.82
22.	22.	Neo4j	Graph DBMS	18.77	+0.83
23.	23.	Firebird	Relational DBMS	16.66	-1.05



Jsonb query

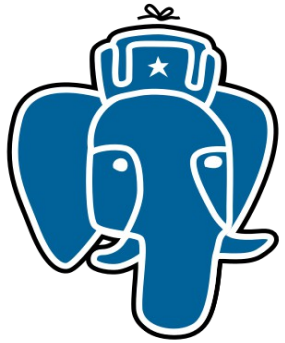
- Currently, one can search jsonb data using
  - Contains operators - jsonb @> jsonb, jsonb <@ jsonb (GIN indexes)
    jb @> '{"tags":[{"term":"NYC"}]}'::jsonb
    Keys should be specified from root
  - Equivalence operator — jsonb = jsonb (GIN indexes)
  - Exists operators — jsonb ? text, jsonb ?! text[], jsonb ?& text[] (GIN indexes)
    jb WHERE jb ?| '{tags,links}'
    Only root keys supported
  - Operators on jsonb parts (functional indexes)
    SELECT ('{"a": {"b":5}}'::jsonb -> 'a'->>'b')::int > 2;
    CREATE INDEX ....USING BTREE ((jb->'a'->>'b')::int);
    Very cumbersome, too many functional indexes



Jsonb query

- Need Jsonb query language
  - More operators on keys, values
  - Types support
  - Schema support (constraints on keys, values)
  - Indexes support
- Introduce Jsquery - textual data type and @@ match operator

jsonb @@ jsquery



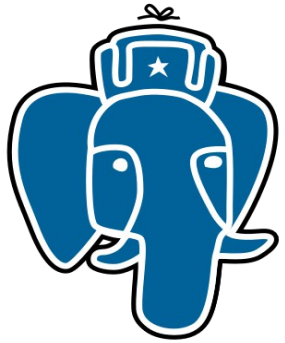
Jsonb query language (Jsquery)

```
expr     ::= path value_expr
           | path '(' expr ')'
           | '(' expr ')'
           | '!' expr
           | expr '&' expr
           | expr '|' expr
```

```
value_expr
         ::= '=' scalar_value
           | IN '(' value_list ')'
           | '=' array
           | '=' '*'
           | '<' NUMERIC
           | '<' '=' NUMERIC
           | '>' NUMERIC
           | '>' '=' NUMERIC
           | '@' '>' array
           | '<' '@' array
           | '&' '&' array
```

```
path     ::= path_elem
           | path '.' path_elem

path_elem
         ::= '*'
           | '#'
           | '%'
           | '$'
           | key

key      ::= STRING
           | true
           | false
           | NUMERIC
           | null
           | IN
```

```
value_list
         ::= scalar_value
           | value_list ',' scalar_value

array    ::= '[' value_list ']'

scalar_value
         ::= null
           | STRING
           | IN
           | true
           | false
           | NUMERIC
```



Jsonb query language (Jsquery)

- # - any element array

```
SELECT '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b.# = 2';
```

- % - any key

```
SELECT '{"a": {"b": [1,2,3]}}'::jsonb @@ '%.b.# = 2';
```

- * - anything

```
SELECT '{"a": {"b": [1,2,3]}}'::jsonb @@ '*.# = 2';
```

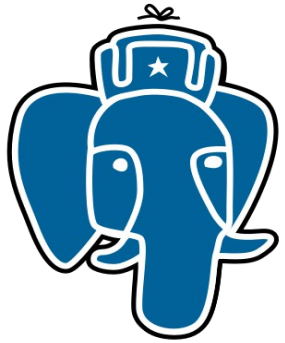
- $ - current element

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b.# ($ = 2 | $ < 3)';
```

- Use "double quotes" for key !

```
select 'a1."12222" < 111'::jsquery;
```

```
path    ::= path_elem
          | path '.' path_elem

path_elem
        ::= '*'
          | '#'
          | '%'
          | '$'
          | key

key     ::= STRING
          | true
          | false
          | NUMERIC
          | null
          | IN
```



Jsonb query language (Jsquery)

- Scalar

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b.# IN (1,2,5)';
```

- Test for key existence

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b = *';
```

- Array overlap

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b && [1,2,5]';
```

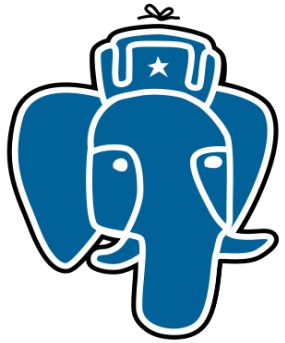
- Array contains

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b @> [1,2]';
```

- Array contained

```
select '{"a": {"b": [1,2,3]}}'::jsonb @@ 'a.b <@ [1,2,3,4,5]';
```

```
value_expr
        ::= '=' scalar_value
          | IN '(' value_list ')'
          | '=' array
          | '=' '*'
          | '<' NUMERIC
          | '<' '=' NUMERIC
          | '>' NUMERIC
          | '>' '=' NUMERIC
          | '@' '>' array
          | '<' '@' array
          | '&' '&' array
```



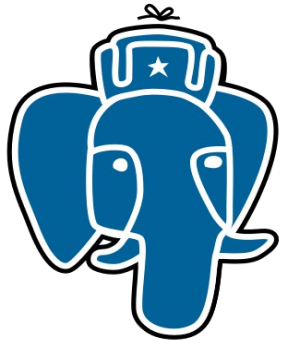
Jsonb query language (Jsquery)

- How many products are similar to "B000089778" and have product_sales_rank in range between 10000-20000 ?
- SQL

  SELECT count(*) FROM jr WHERE (jr->>'product_sales_rank')::int > 10000 and (jr->> 'product_sales_rank')::int < 20000 and
  ....boring stuff
- Jsquery

  SELECT count(*) FROM jr WHERE jr @@ ' similar_product_ids && ["B000089778"] & product_sales_rank($ > 10000 & $ < 20000)'
- Mongodb

  db.reviews.find({ $and :[{similar_product_ids: { $in ["B000089778"]}}, {product_sales_rank:{$gt:10000, $lt:20000}}] }).count()



Jsonb query language (Jsquery)

explain(analyze, buffers) select count(*) from jb where **jb @> '{"tags":[{"term":"NYC"}]}'::jsonb;**

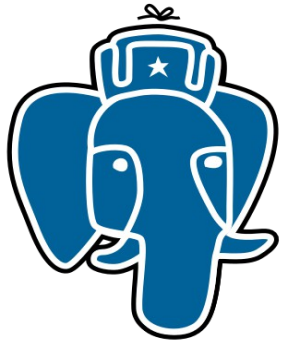
```
                                                  QUERY PLAN
-------------------------------------------------------------------------------------------------------------------
 Aggregate  (cost=191517.30..191517.31 rows=1 width=0) (actual time=1039.422..1039.423 rows=1 loops=1)
   Buffers: shared hit=97841 read=78011
   ->  Seq Scan on jb  (cost=0.00..191514.16 rows=1253 width=0) (actual time=0.006..1039.310 rows=285 loops=1)
         Filter: (jb @> '{"tags": [{"term": "NYC"}]}'::jsonb)
         Rows Removed by Filter: 1252688
         Buffers: shared hit=97841 read=78011
 Planning time: 0.074 ms
```

Execution time: 1039.444 ms

explain(analyze,costs off) select count(*) from jb where **jb @@ 'tags.#.term = "NYC"';**

```
                        QUERY PLAN
-----------------------------------------------------------
 Aggregate (actual time=891.707..891.707 rows=1 loops=1)
   ->  Seq Scan on jb (actual time=0.010..891.553 rows=285 loops=1)
         Filter: (jb @@ '"tags".#."term" = "NYC"'::jsquery)
         Rows Removed by Filter: 1252688
```

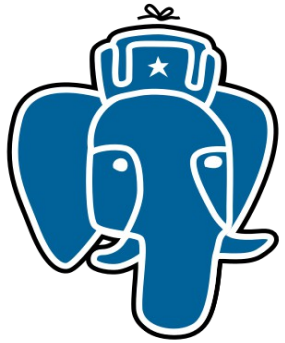
Execution time: 891.745 ms



Jsquery (indexes)

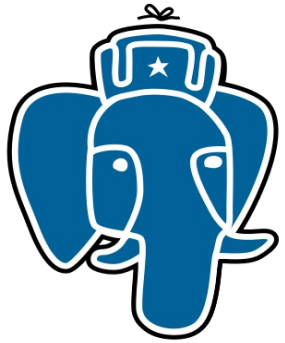
- GIN opclasses with jsquery support
  - jsonb_value_path_ops — use Bloom filtering for key matching
    {"a":{"b":{"c":10}}} → 10.(bloom(a) or bloom(b) or bloom(c))
    - Good for key matching (wildcard support) , not good for range query
  - jsonb_path_value_ops — hash path (like jsonb_path_ops)
    {"a":{"b":{"c":10}}} → hash(a.b.c).10
    - No wildcard support, no problem with ranges

```
                                 List of relations
 Schema |           Name            | Type  |  Owner   |     Table     |  Size   | Description
--------+---------------------------+-------+----------+---------------+---------+-------------
 public | jb                        | table | postgres |               | 1374 MB |
 public | jb_value_path_idx         | index | postgres | jb            | 306 MB  |
 public | jb_gin_idx                | index | postgres | jb            | 544 MB  |
 public | jb_path_value_idx         | index | postgres | jb            | 306 MB  |
 public | jb_path_idx               | index | postgres | jb            | 251 MB  |
```



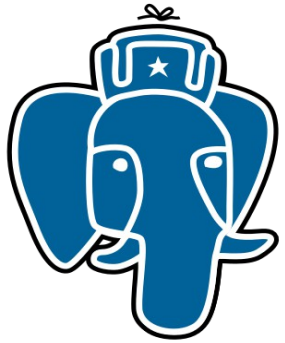
Jsquery (indexes)

```
explain( analyze,costs off) select count(*) from jb where jb @@ 'tags.#.term = "NYC"';
                                QUERY PLAN
-------------------------------------------------------------------------------------------------
 Aggregate (actual time=0.609..0.609 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb (actual time=0.115..0.580 rows=285 loops=1)
         Recheck Cond: (jb @@ '"tags".#."term" = "NYC"'::jsquery)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on jb_value_path_idx (actual time=0.073..0.073 rows=285 loops=1)
               Index Cond: (jb @@ '"tags".#."term" = "NYC"'::jsquery)
 Execution time: 0.634 ms
(7 rows)
```



Jsquery (indexes)

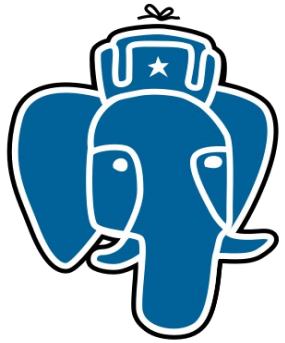
```
explain( analyze,costs off) select count(*) from jb where jb @@ '*.term = "NYC"';
                                QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate (actual time=0.688..0.688 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb (actual time=0.145..0.660 rows=285 loops=1)
         Recheck Cond: (jb @@ '*."term" = "NYC"'::jsquery)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on jb_value_path_idx (actual time=0.113..0.113 rows=285 loops=1)
               Index Cond: (jb @@ '*."term" = "NYC"'::jsquery)
 Execution time: 0.716 ms
(7 rows)
```



Citus dataset

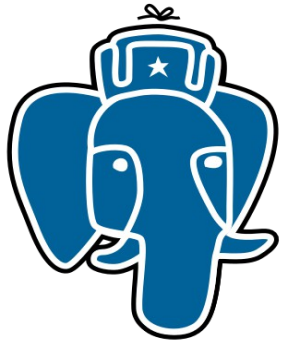
- 3023162 reviews from Citus 1998-2000 years
- 1573 MB


```
{
  "customer_id": "AE22YDHSBFYIP",
  "product_category": "Business & Investing",
  "product_group": "Book",
  "product_id": "1551803542",
  "product_sales_rank": 11611,
  "product_subcategory": "General",
  "product_title": "Start and Run a Coffee Bar (Start & Run a)",
  "review_date": {
    "$date": 31363200000
  },
  "review_helpful_votes": 0,
  "review_rating": 5,
  "review_votes": 10,
  "similar_product_ids": [
    "0471136174",
    "0910627312",
    "047112138X",
    "0786883561",
    "0201570483"
  ]
}
```



Jsquery (indexes)

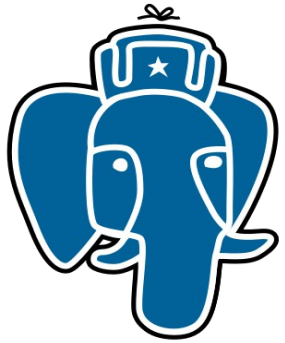
```
explain (analyze, costs off) select count(*) from jr where
jr @@  ' similar_product_ids && ["B000089778"]';
                                QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate (actual time=0.359..0.359 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=0.084..0.337 rows=185 loops=1)
         Recheck Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
         Heap Blocks: exact=107
         ->  Bitmap Index Scan on jr_path_value_idx (actual time=0.057..0.057 rows=185 loops=1)
               Index Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
 Execution time: 0.394 ms
(7 rows)
```



Jsquery (indexes)

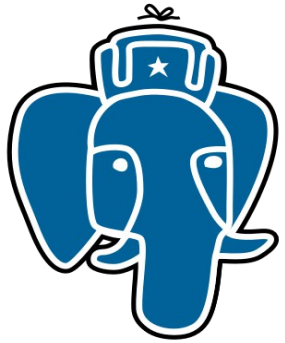
- No statistics, no planning :(

```
explain (analyze, costs off) select count(*) from jr where
 jr @@ ' similar_product_ids && ["B000089778"] & product_sales_rank( $ > 10000 & $  < 20000)';
                                                  QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=126.149..126.149 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=126.057..126.143 rows=45 loops=1)
         Recheck Cond: (jr @@ '("similar_product_ids" && ["B000089778"] &
 "product_sales_rank"($ > 10000 & $ < 20000))'::jsquery)
         Heap Blocks: exact=45
         ->  Bitmap Index Scan on jr_path_value_idx (actual time=126.029..126.029 rows=45 loops=1)
               Index Cond: (jr @@ '("similar_product_ids" && ["B000089778"] &
"product_sales_rank"($ > 10000 & $ < 20000))'::jsquery)
 Execution time: 129.309 ms !!!   No statistics
(7 rows)
```



MongoDB 2.6.0

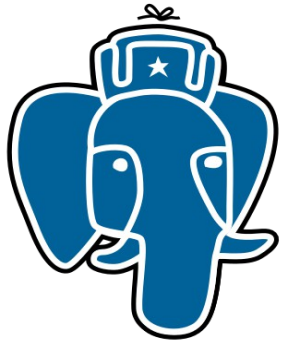
```
db.reviews.find(  {  $and :[ {similar_product_ids: { $in:["B000089778"]}},    {product_sales_rank:{$gt:10000, $lt:20000}}] } )
.explain()
{
        "n" : 45,
        .....................
        "millis" : 7,
        "indexBounds" : {
                "similar_product_ids" : [                    index size = 400 MB just for similar_product_ids !!!
                        [
                                "B000089778",
                                "B000089778"
                        ]
                ]
        },
}
```



Jsquery (indexes)

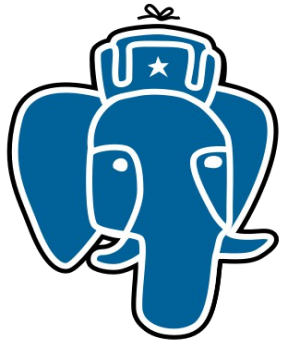
- Need statistics and planner support !

```
explain (analyze,costs off) select count(*) from jr where
jr @@ ' similar_product_ids && ["B000089778"]'
and  (jr->>'product_sales_rank')::int>10000 and (jr->>'product_sales_rank')::int<20000;
-------------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=0.479..0.479 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=0.079..0.472 rows=45 loops=1)
         Recheck Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
         Filter: ((((jr ->> 'product_sales_rank'::text))::integer > 10000) AND
(((jr ->> 'product_sales_rank'::text))::integer < 20000))
         Rows Removed by Filter: 140
         Heap Blocks: exact=107
         ->  Bitmap Index Scan on jr_path_value_idx (actual time=0.041..0.041 rows=185 loops=1)
               Index Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
 Execution time: 0.506 ms
(9 rows)
```



Contrib/jsquery

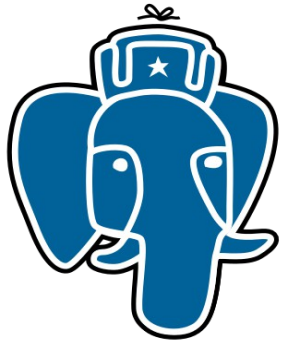
- PostgreSQL has potential to execute jsquery for 0.5 ms vs Mongo 7 ms !
  - Need statistics
  - Need planner
- Availability
  - Jsquery + opclasses are available as extensions
  - Grab it from https://github.com/akorotkov/jsquery (branch master) ,
    we need your feedback !
  - We will release it after PostgreSQL 9.4 release
  - Need real sample data and queries !



Better indexing ...

- GIN is a proven and effective index access method
- Need indexing for jsonb with operations on paths (no hash!) and values
  - B-tree in entry tree is not good - length limit, no prefix compression

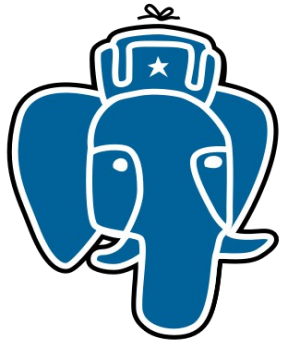
```
                                 List of relations
 Schema |             Name              | Type  |  Owner   |     Table      |  Size   | Description
--------+-------------------------------+-------+----------+----------------+---------+-------------
 public | jb                            | table | postgres |                | 1374 MB |
 public | jb_uniq_paths                 | table | postgres |                | 912 MB  |
 public | jb_uniq_paths_btree_idx       | index | postgres | jb_uniq_paths | 885 MB  |text_pattern_ops
 public | jb_uniq_paths_spgist_idx      | index | postgres | jb_uniq_paths | 598 MB  |now much less !
```



Better indexing ...

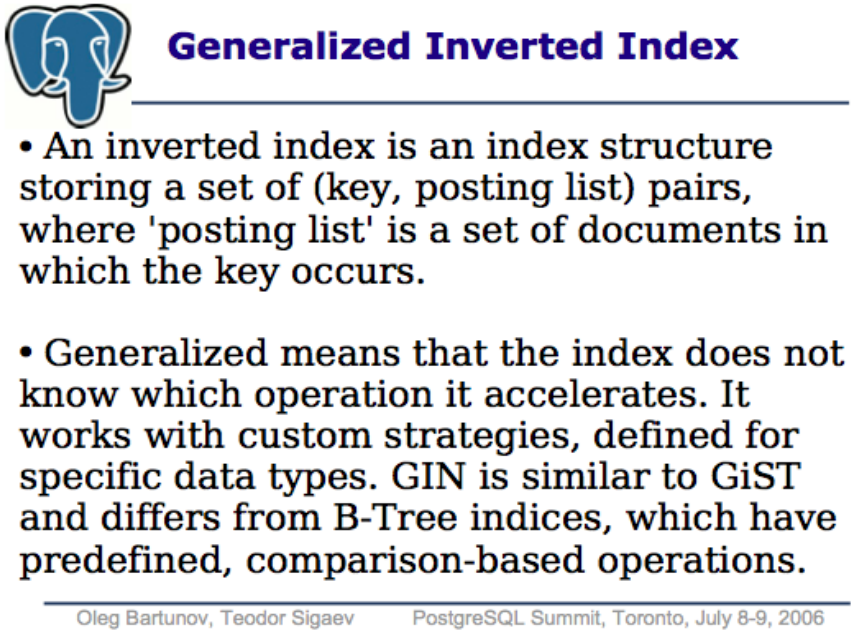
- Provide interface to change hardcoded B-tree in Entry tree
  - Use spgist opclass for storing paths and values as is (strings hashed in values)
- We may go further - provide interface to change hardcoded B-tree in posting tree
  - GIS aware full text search !
- New index access method

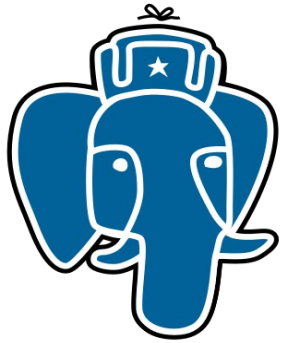
```
CREATE INDEX ... USING VODKA
```



GIN History

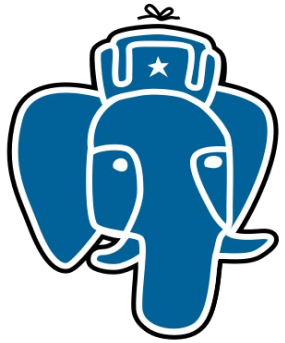
- Introduced at PostgreSQL Anniversary Meeting in Toronto, Jul 7-8, 2006 by Oleg Bartunov and Teodor Sigaev





GIN History

- Introduced at PostgreSQL Anniversary Meeting in Toronto, Jul 7-8, 2006 by Oleg Bartunov and Teodor Sigaev
- Supported by JFG Networks (France)
- «Gin stands for Generalized Inverted iNdex and should be considered as a genie, not a drink.»
- Alexander Korotkov, Heikki Linnakangas have joined GIN++ development in 2013



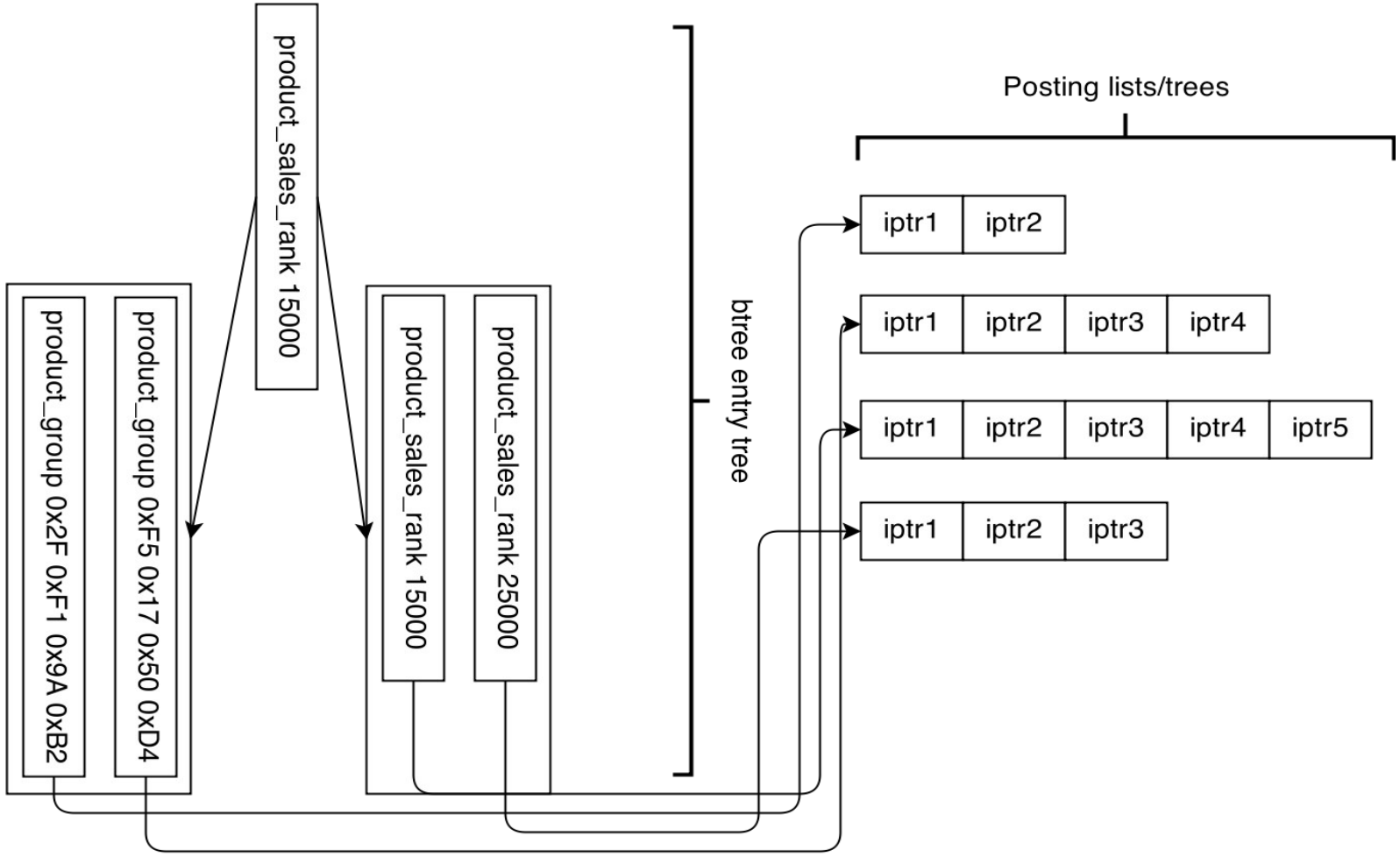
GIN History

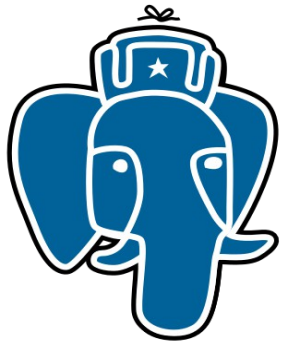
- From GIN Readme, posted in -hackers, 2006-04-26

```
TODO
----

Nearest future:

  * Opclasses for all types (no programming, just many catalog changes).

Distant future:

  * Replace B-tree of entries to something like GiST (VODKA ! 2014)
  * Add multicolumn support
  * Optimize insert operations (background index insertion)
```

GIN index structure for jsonb

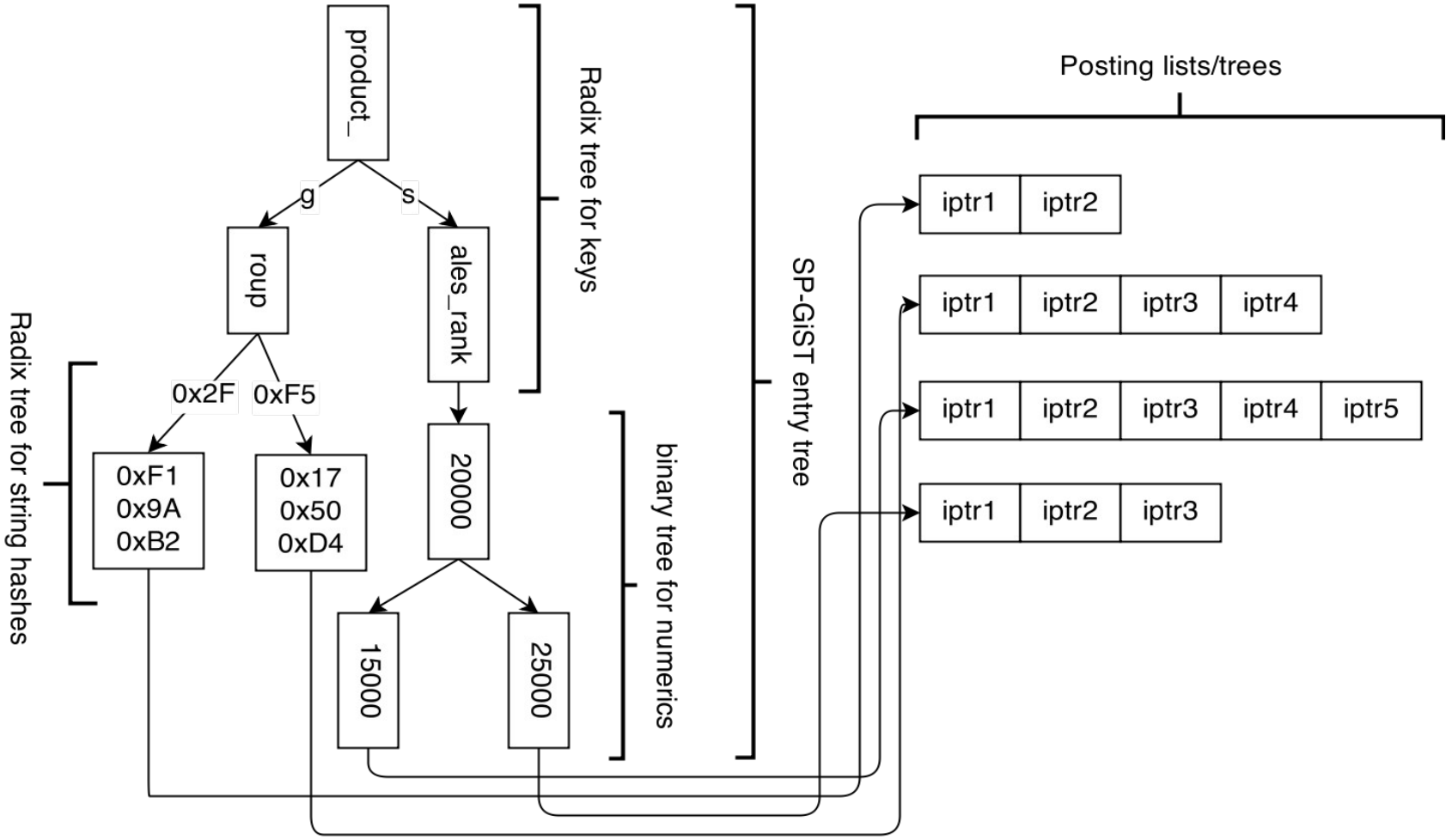
```
{
   "product_group": "Book",
   "product_sales_rank": 15000
},
{
   "product_group": "Music",
   "product_sales_rank": 25000
}
```

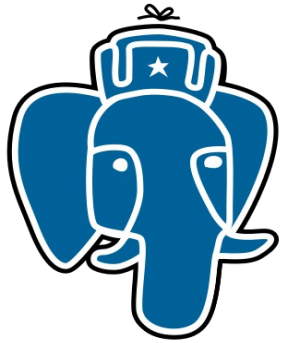




Vodka index structure for jsonb

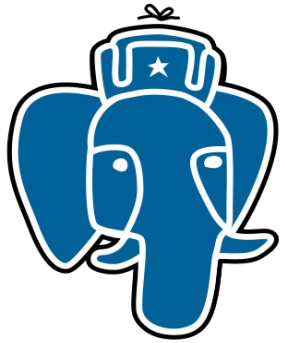
```
{
   "product_group": "Book",
   "product_sales_rank": 15000
},
{
   "product_group": "Music",
   "product_sales_rank": 25000
}
```





Vodka distilling instructions

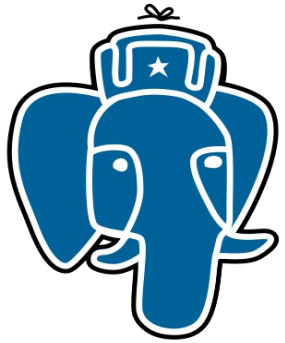
- config — configures parameters
  - entry tree opclass
  - equality operator
- compare — compares entry tree parameters (as in GIN)
- extract value — decompose datum into entries (as in GIN)
- extract query — decompose query into keys:
  - operator to scan entry tree
  - argument to scan entry tree
- consistent — check if item satisfies query (as in GIN)
- triconsistent — check if item satisfies query in ternary logic (as in GIN)



CREATE INDEX ... USING VODKA

- Delicious bookmarks, mostly text data

```
set maintenance_work_mem = '1GB';

                                List of relations
 Schema |        Name          | Type  |  Owner   | Table |  Size   | Description
--------+----------------------+-------+----------+-------+---------+-------------
 public | jb                   | table | postgres |       | 1374 MB |  1252973 rows
 public | jb_value_path_idx    | index | postgres | jb    | 306 MB  |   98769.096
 public | jb_gin_idx           | index | postgres | jb    | 544 MB  |  129860.859
 public | jb_path_value_idx    | index | postgres | jb    | 306 MB  |  100560.313
 public | jb_path_idx          | index | postgres | jb    | 251 MB  |   68880.320
 public | jb_vodka_idx         | index | postgres | jb    | 409 MB  |  185362.865
 public | jb_vodka_idx5        | index | postgres | jb    | 325 MB  |  174627.234 new spgist
(6 rows)
```



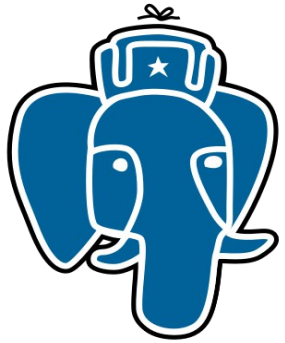
CREATE INDEX ... USING VODKA

```
select count(*) from jb where jb @@ 'tags.#.term = "NYC"';
-------------------------------------------------------------------------------------
 Aggregate (actual time=0.423..0.423 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb (actual time=0.146..0.404 rows=285 loops=1)
         Recheck Cond: (jb @@ '"tags".#."term" = "NYC"'::jsquery)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on jb_vodka_idx (actual time=0.108..0.108 rows=285 loops=1)
               Index Cond: (jb @@ '"tags".#."term" = "NYC"'::jsquery)
```

Execution time: 0.456 ms (0.634 ms, GIN jsonb_value_path_ops)

```
select count(*) from jb where jb @@ '*.term = "NYC"';
-------------------------------------------------------------------------------------
 Aggregate (actual time=0.495..0.495 rows=1 loops=1)
   ->  Bitmap Heap Scan on jb (actual time=0.245..0.474 rows=285 loops=1)
         Recheck Cond: (jb @@ '*."term" = "NYC"'::jsquery)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on jb_vodka_idx (actual time=0.214..0.214 rows=285 loops=1)
               Index Cond: (jb @@ '*."term" = "NYC"'::jsquery)
```

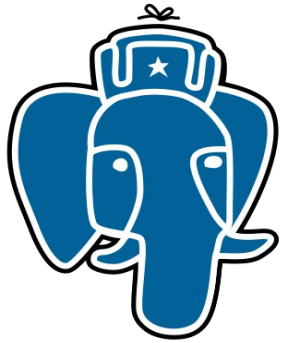
Execution time: 0.526 ms (0.716 ms, GIN jsonb_path_value_ops)



CREATE INDEX … USING VODKA

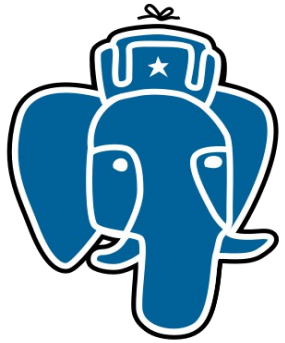
- CITUS data, text and numeric

```
set maintenance_work_mem = '1GB';

                              List of relations
 Schema |         Name          | Type  |  Owner   | Table |  Size   | Description
--------+-----------------------+-------+----------+-------+---------+-------------
 public | jr                    | table | postgres |       | 1573 MB |  3023162 rows
 public | jr_value_path_idx     | index | postgres | jr    | 196 MB  |  79180.120
 public | jr_gin_idx            | index | postgres | jr    | 235 MB  | 111814.929
 public | jr_path_value_idx     | index | postgres | jr    | 196 MB  |  73369.713
 public | jr_path_idx           | index | postgres | jr    | 180 MB  |  48981.307
 public | jr_vodka_idx3         | index | postgres | jr    | 240 MB  | 155714.777
 public | jr_vodka_idx4         | index | postgres | jr    | 211 MB  | 169440.130 new spgist

(6 rows)
```



CREATE INDEX ... USING VODKA

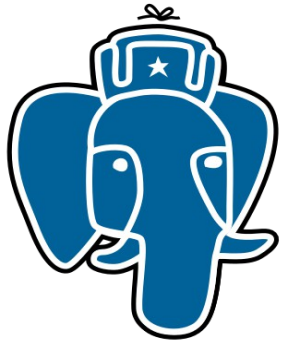
```
explain (analyze, costs off) select count(*) from jr where jr @@  ' similar_product_ids && ["B000089778"]';
                                QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate (actual time=0.200..0.200 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=0.090..0.183 rows=185 loops=1)
         Recheck Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
         Heap Blocks: exact=107
         ->  Bitmap Index Scan on jr_vodka_idx (actual time=0.077..0.077 rows=185 loops=1)
               Index Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
 Execution time: 0.237 ms (0.394 ms, GIN jsonb_path_value_idx)
(7 rows)
```



CREATE INDEX ... USING VODKA

- No statistics, no planning :(

```
select count(*) from jr where  jr @@ ' similar_product_ids && ["B000089778"]
 & product_sales_rank( $ > 10000 & $  < 20000)';
                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=127.471..127.471 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=127.416..127.461 rows=45 loops=1)
         Recheck Cond: (jr @@ '("similar_product_ids" && ["B000089778"]
& "product_sales_rank"($ > 10000 & $ < 20000))'::jsquery)
         Heap Blocks: exact=45
         ->  Bitmap Index Scan on jr_vodka_idx (actual time=127.400..127.400 rows=45 loops=1)
               Index Cond: (jr @@ '("similar_product_ids" && ["B000089778"]
& "product_sales_rank"($ > 10000 & $ < 20000))'::jsquery)
 Execution time: 130.051 ms
(7 rows)
```

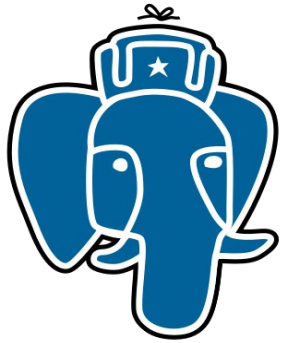


CREATE INDEX ... USING VODKA

- No statistics, no planning :(

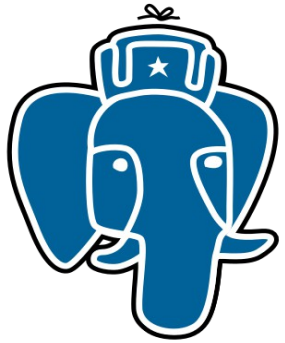
```
select count(*) from jr where jr @@ ' similar_product_ids && ["B000089778"]'
and  (jr->>'product_sales_rank')::int>10000 and (jr->>'product_sales_rank')::int<20000;
                                        QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=0.401..0.401 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=0.109..0.395 rows=45 loops=1)
         Recheck Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
         Filter: ((((jr ->> 'product_sales_rank'::text))::integer > 10000)
AND (((jr ->> 'product_sales_rank'::text))::integer < 20000))
         Rows Removed by Filter: 140
         Heap Blocks: exact=107
         ->  Bitmap Index Scan on jr_vodka_idx (actual time=0.079..0.079 rows=185 loops=1)
               Index Cond: (jr @@ '"similar_product_ids" && ["B000089778"]'::jsquery)
 Execution time: 0.431 ms  (7 ms, MongoDB)
(9 rows)
```

BIG Potential !



CREATE INDEX ... USING VODKA

```
select count(*) from jr where jr @@ 'similar_product_ids && ["B000089778"] & review_rating($> 3 & $<5)';
                                        QUERY PLAN
-----------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=98.313..98.314 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=98.273..98.307 rows=32 loops=1)
         Recheck Cond: (jr @@ '("similar_product_ids" && ["B000089778"] & "review_rating"($ > 3 & $ < 5))'::jsquery)
         Heap Blocks: exact=16
         ->  Bitmap Index Scan on jr_path_value_idx (actual time=98.254..98.254 rows=32 loops=1)
               Index Cond: (jr @@ '("similar_product_ids" && ["B000089778"] & "review_rating"($ > 3 & $ < 5))'::jsquery)
 Execution time: 99.873 ms

-----------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=1.521..1.521 rows=1 loops=1)
   ->  Bitmap Heap Scan on jr (actual time=1.503..1.515 rows=32 loops=1)
         Recheck Cond: (jr @@ '("similar_product_ids" && ["B000089778"] & "review_rating"($ > 3 & $ < 5))'::jsquery)
         Heap Blocks: exact=16
         ->  Bitmap Index Scan on jr_vodka_idx (actual time=1.498..1.498 rows=32 loops=1)
               Index Cond: (jr @@ '("similar_product_ids" && ["B000089778"] & "review_rating"($ > 3 & $ < 5))'::jsquery)
 Execution time: 1.550 ms  (FAST SCAN !)
```



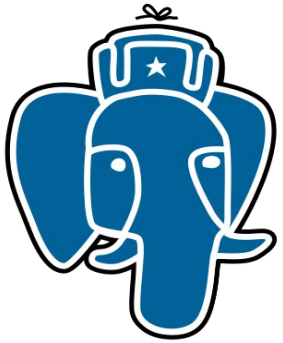
Need positional information for both GIN and VODKA

```
[{"f1": 23, "f2": 46}, {"f1": 42, "f2": 24}, {"f1": 98, "f2": 2}, {"f1": 62, "f2": 70},
 {"f1": 66, "f2": 41}, {"f1": 32, "f2": 95}, {"f1": 11, "f2": 64}, {"f1": 20, "f2": 27},
 {"f1": 45, "f2": 42}, {"f1": 14, "f2": 53}]
```

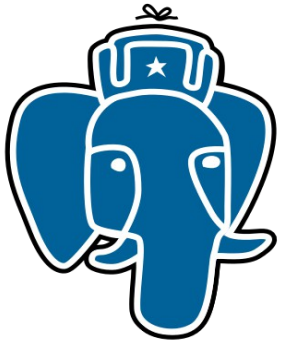
```
# explain analyze select * from test where v @@ '#(f1 = 10 & f2 = 20)';
```

- HUGE RECHECK!

```
                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------
 Bitmap Heap Scan on test  (cost=191.75..3812.68 rows=1000 width=32)
(actual time=14.576..35.039 rows=1005 loops=1)
   Recheck Cond: (v @@ '#("f1" = 10 & "f2" = 20)'::jsquery)
   Rows Removed by Index Recheck: 7998
   Heap Blocks: exact=8416
   ->  Bitmap Index Scan on test_idx  (cost=0.00..191.50 rows=1000 width=0)
       (actual time=13.396..13.396 rows=9003 loops=1)
         Index Cond: (v @@ '#("f1" = 10 & "f2" = 20)'::jsquery)
 Execution time: 35.329 ms
```

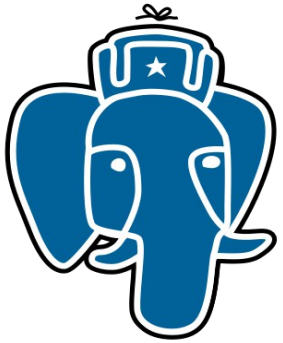


There are can be different flavors of Vodka

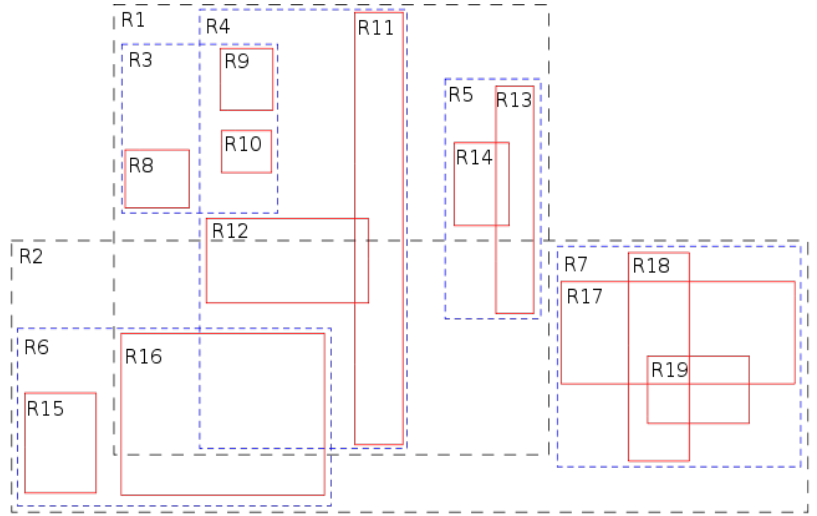


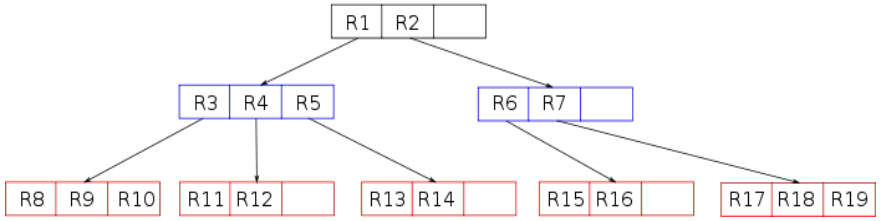
Spaghetti indexing …

Find twirled spaghetti

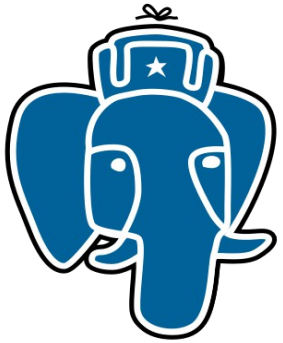


Spaghetti indexing …

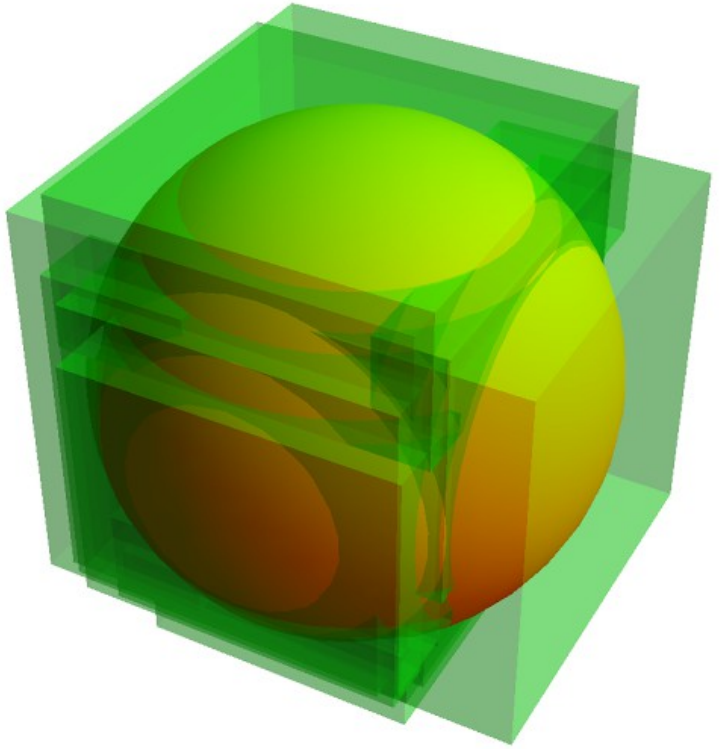




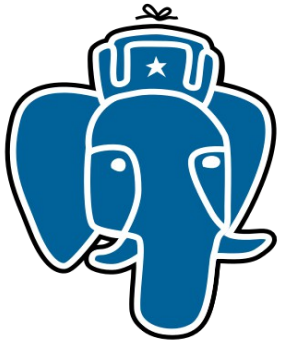
R-tree fails here – bounding box of each separate spaghetti is the same



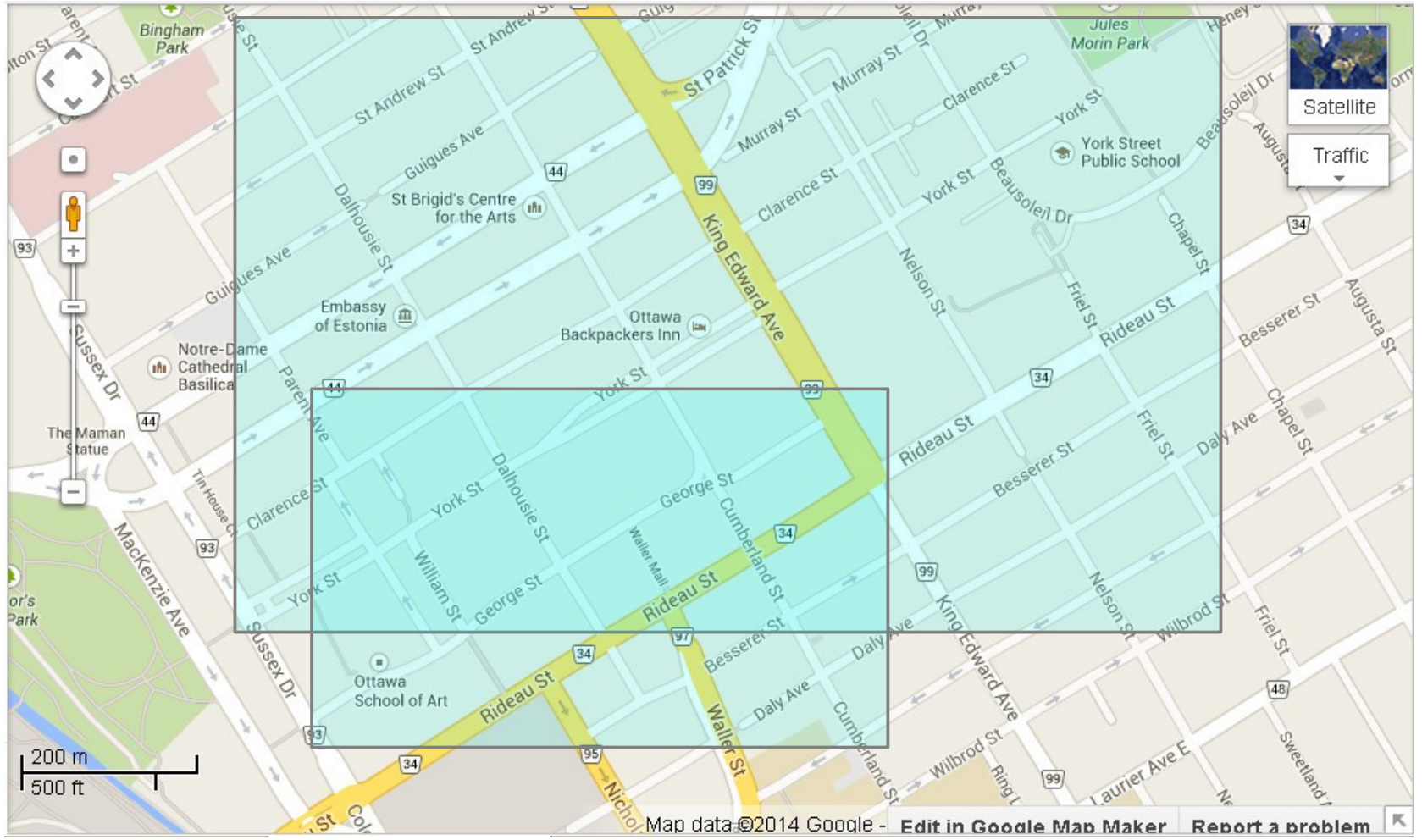
Spaghetti indexing …

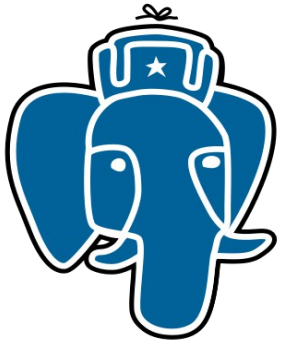


R-tree fails here – bounding box of each separate spaghetti is the same

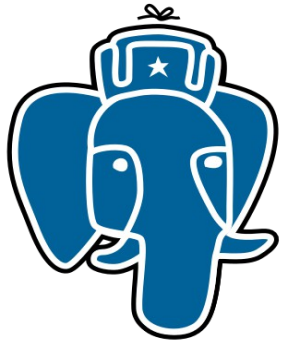


Ottawa downtown: York and George streets

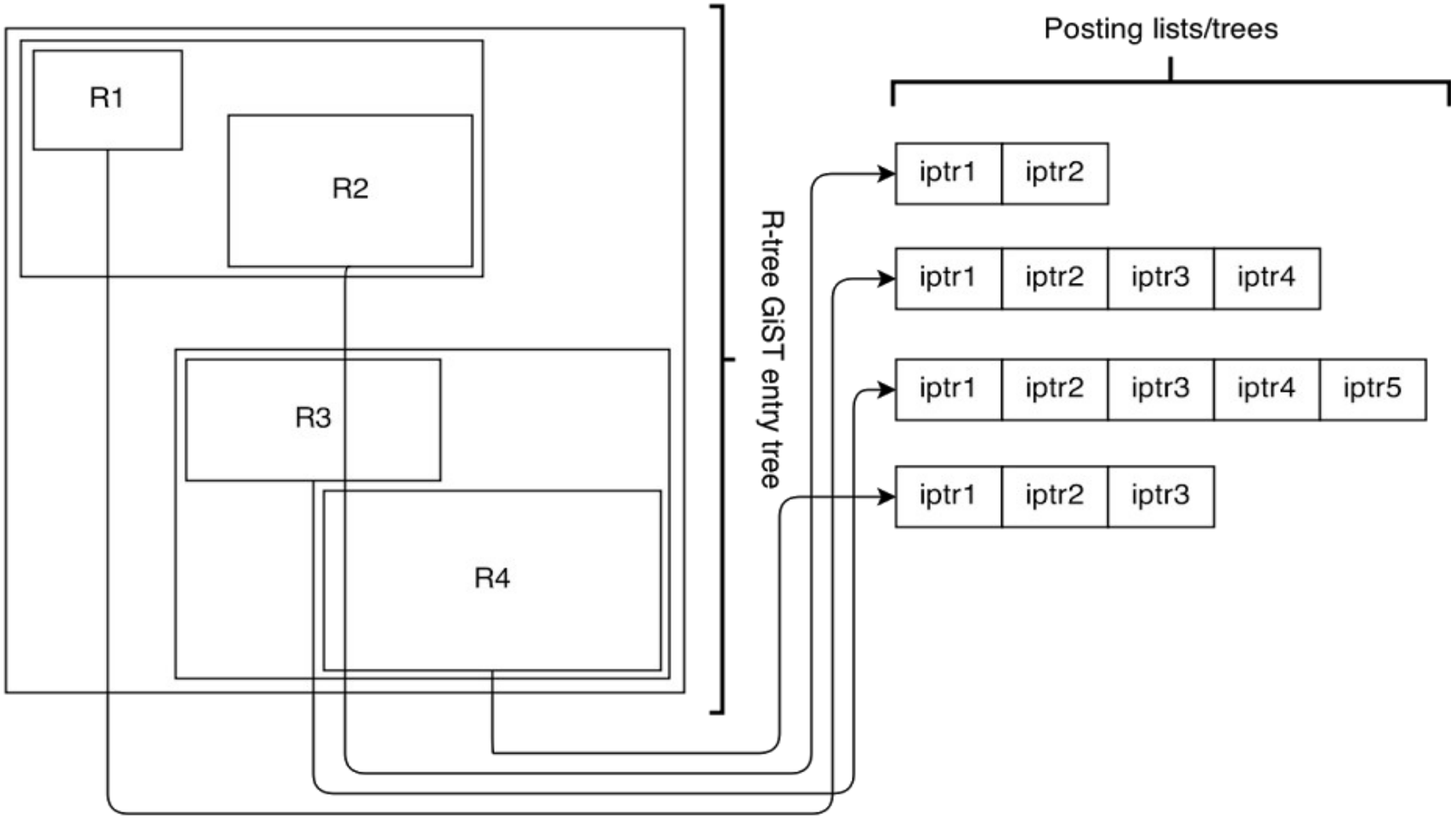


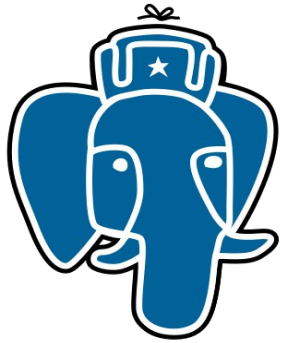


Idea: Use multiple boxes



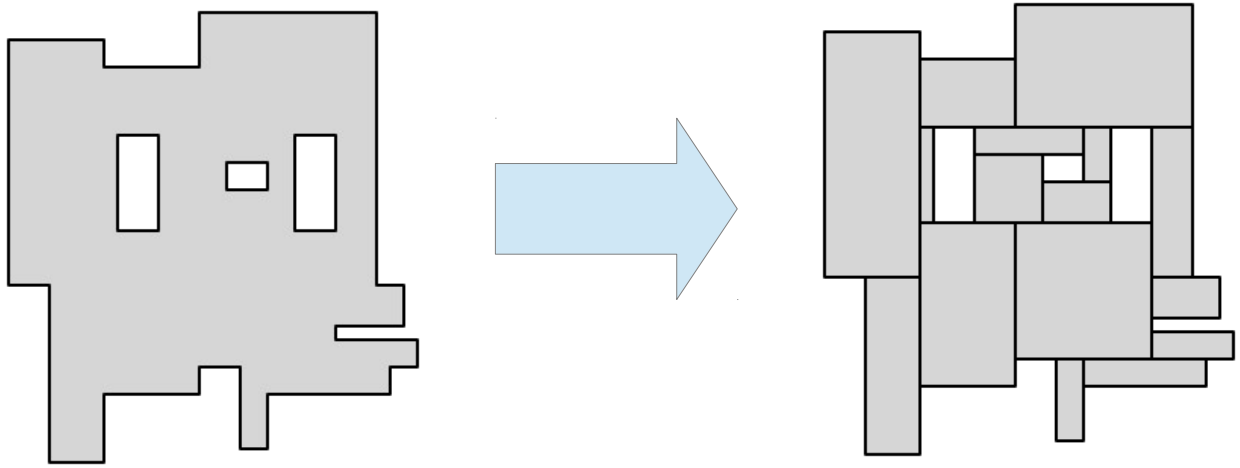
Rtree Vodka

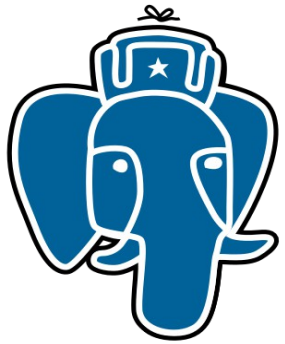

R1
R2
R3
R4
R-tree GiST entry tree
Posting lists/trees
iptr1
iptr2
iptr1
iptr2
iptr3
iptr4
iptr1
iptr2
iptr3
iptr4
iptr5
iptr1
iptr2
iptr3



Rtree Vodka

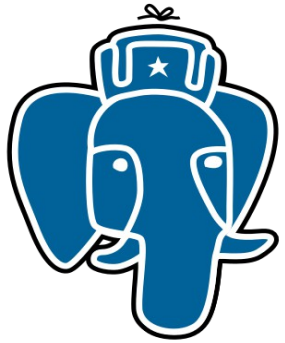
- R-tree based on GiST as Entry tree
- An algorithm for covering polygons with rectangles ?
- Need support — POSTGIS ?





Vodka problems

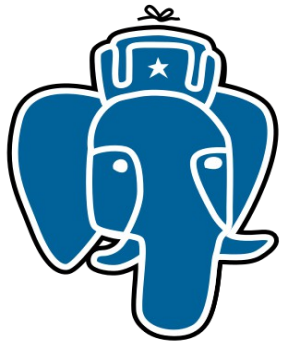
- How to update ItemPointer in entry tree? Insert new then vacuum is weird and expensive. amupdateiptr?
- Now it's hard to get OIDs of extension opclass or operator.
- Storing entry tree in separate file: is it correct? What infrastructure should handle it?
- TODO: replacing posting tree with arbitrary access method. Have to share multiple indexes in same file. How am interface can handle it? Pass root block number to am? How to vacuum?



Summary

- contrib/jsquery for 9.4
  - Jsquery - Jsonb Query Language
  - Two GIN opclasses with jsquery support
  - Grab it from https://github.com/akorotkov/jsquery (branch master)
- Prototype of VODKA access method
- Plans for improving indexing infrastructure
- This work was supported by heroku


Meet us in Madrid with better
VODKA !



VODKA Optimized Dendriform Keys Array