Schema-less PostgreSQL

Current and Future

September, 2014, Tokyo, Japan

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

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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

- The problem
- Hstore
- Introduction to jsonb indexing
- Jquery - Jsonb Query Language
- Exercises on jsonb GIN opclasses with Jquery support
- VODKA access method
The problem

• The world of data and applications is changing
• BIG DATA (Volume of data, Velocity of data in-out, Variety of data)
• Web applications are service-oriented
  • Service itself can aggregate data, check consistency of data
  • High concurrency, simple queries
  • Simple database (key-value) is ok
  • Eventual consistency is ok, no ACID overhead
• Application needs faster releases
• NoSQL databases match all of these — scalable, efficient, fault-tolerant, no rigid schema, ready to accept any data.
NoSQL

- Key-value databases
  - Ordered k-v for ranges support
- Column family (column-oriented) stores
  - Big Table — value has structure:
    - column families, columns, and timestamped versions (maps-of maps-of maps)
- Document databases
  - Value has arbitrary structure
- Graph databases — evolution of ordered-kv
A diagram illustrating different data models, including Key-Value, Ordered Key-Value, Big Table, Document, and Graph. Each model is represented with a series of connected nodes and arrows, indicating the relationships and data flow.

An example of Semi-Structured Data is shown, with a JSON-like structure:

```json
"employee": {
  "name": "Mohana Pillai",
  "position": "Delivery",
  "projects": [
    {
      "name": "Easy Sign"
    }
  ],
  "skills": []
}
```

The text mentions a confidential word or number, indicating its importance in data security, and provides a note about combining data to create an ID, with a restriction on the length of the combination.
The problem

• What if application needs ACID and flexibility of NoSQL?
• Relational databases work with data with schema known in advance
• One of the major complaints to relational databases is rigid schema.
  It's not easy to change schema online (ALTER TABLE ... ADD COLUMN...)
• Application should wait for schema changing, infrequent releases
• NoSQL uses json format, why not have it in relational database?

JSON in PostgreSQL
This is the challenge!
Challenge to PostgreSQL!

• Full support of semi-structured data in PostgreSQL
  • Storage
  • Operators and functions
  • Efficiency (fast access to storage, indexes)
  • Integration with CORE (planner, optimiser)

• Actually, PostgreSQL is schema-less database since 2003 — hstore, one of the most popular extension!
Google insights about hstore
Introduction to Hstore

<table>
<thead>
<tr>
<th>id</th>
<th>col1</th>
<th>col2</th>
<th>col3</th>
<th>col4</th>
<th>col5</th>
</tr>
</thead>
</table>

A lot of columns
key1, …. keyN

• The problem:
• Total number of columns may be very large
• Only several fields are searchable (used in WHERE)
• Other columns are used only to output
  • These columns may not known in advance
• Solution
  • New data type (hstore), which consists of (key,value) pairs (a'la perl hash)
## Introduction to Hstore

<table>
<thead>
<tr>
<th>id</th>
<th>col1</th>
<th>col2</th>
<th>col3</th>
<th>col4</th>
<th>col5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Easy to add `key=>value` pair
- No need to change schema, just change hstore.
- Schema-less PostgreSQL in 2003!
Introduction to hstore

• Hstore — key/value binary 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,......)

• Hstore provides PostgreSQL schema-less feature!
  • Faster releases, no problem with schema upgrade
Hstore binary storage

Pairs are lexicographically ordered by key

<table>
<thead>
<tr>
<th>First key</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>i-th key</td>
<td>HEntry[i*2 - 1]</td>
<td>HEntry[i*2]</td>
</tr>
<tr>
<td>i-th value</td>
<td>HEntry[i*2]</td>
<td>HEntry[i*2 + 1]</td>
</tr>
</tbody>
</table>
Hstore limitations

- Levels: unlimited
- Number of elements in array: $2^{31}$
- Number of pairs in hash: $2^{31}$
- Length of string: $2^{31}$ bytes

$2^{31}$ bytes = 2 GB
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 первая 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 первой аналог
4 hstore || hstore - конкатенация, аналог в perl %a= (%b, %c );
5 text=text - возвращает hstore
   select 'a'='b';
   ?column?
   -----{}
   "a"="b"

Все примеры есть в sql/hstore.sql
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
Inverted Index

Report Index

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Btree
Entry tree
Posting trees
Inverted Index

Report Index

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- attitude measurement, 59, 61
- automatic test equipment, 71
- automatic testing, 24
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B

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- compressive strength, 54
- compressors, 29
- computational fluid dynamics, 23, 29
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- concurrent engineering, 14
- contact resistance, 47, 66
- converters, 22
- coplanar waveguide components, 40
- Couette flow, 21
- creep, 17
- crystallisation, 64
- current density, 13, 16

E

QUERY: compensation accelerometers

INDEX: accelerometers compensation
- 5, 10, 25, 28, 30, 36, 58, 59, 61, 73, 74
- 30, 68

RESULT: 30
GIN improvements

- GIN in 9.4 is greatly improved
  - Posting lists compression (varbyte encoding) — smaller indexes
    - 9.3: always 6 bytes (4 bytes blockNumber, 2 bytes offset): 90 bytes
      \((0, 8) (0, 14) (0, 17) (0, 22) (0, 26) (0, 33) (0, 34) (0, 35) (0, 45) (0, 47) (0, 48) (1, 3) (1, 4) (1, 6) (1, 8)\)
    - 9.4: 1-6 bytes per each item, deltas from previous item: 21 bytes
      \((0, 8) +6 +3 +5 +4 +7 +1 +1 +10 +2 +1 +2051 +1 +2 +2\)
    - SELECT \(g \% 10\) FROM generate_series(1,10000000) \(g\); 11Mb vs 58Mb
  - Fast scan of posting lists - «rare & frequent» queries much faster
    - 9.3: read posting lists for «rare» and «frequent» and join them
      Time(frequent & rare) ~ Time(frequent)
    - 9.4: start from posting list for «rare» and skip «frequent» list if no match
      Time(frequent & rare) ~ Time(rare)
Hstore is DEAD ? No !

• How hstore benefits by GIN improvement in 9.4 ?

*GIN stands for Generalized Inverted Index, so virtually all data types, which use GIN, get benefit !*

• Default hstore GIN opclass considers keys and values separately
• Keys are «frequent», value are «rare»
• Contains query: hstore @> 'key=>value' improved a lot for «rare» values
• Index size is smaller, less io
Hstore 9.3 vs 9.4

Total: 7240858 geo records:

"fcode"=>"RFSU",
"point"=>"(8.85,112.53333)",
"fclass"=>"U",
"asciiname"=>"London Reefs",
"elevation"=>NULL,
"geonameid"=>"1879967",
"population"=>"0"

Query:
SELECT count(*) FROM geo WHERE geo @> 'fcode=>STM';

gin_hstore_ops: index keys and values
gin_hstore_bytea_ops = gin_hstore_ops, no collation comparison
gin_hstore_hash_ops: index hash(key.value)
Hstore 9.3 vs 9.4

### 9.3

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Owner</th>
<th>Table</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>geo</td>
<td>table</td>
<td>postgres</td>
<td></td>
<td>1352 MB</td>
</tr>
<tr>
<td>geo_hstore_bytea_ops</td>
<td>index</td>
<td>postgres</td>
<td>geo</td>
<td>1680 MB</td>
</tr>
<tr>
<td>geo_hstore_hash_ops_idx</td>
<td>index</td>
<td>postgres</td>
<td>geo</td>
<td>1073 MB</td>
</tr>
</tbody>
</table>

### 9.4

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Owner</th>
<th>Table</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>geo</td>
<td>table</td>
<td>postgres</td>
<td></td>
<td>1352 MB</td>
</tr>
<tr>
<td>geo_hstore_bytea_ops</td>
<td>index</td>
<td>postgres</td>
<td>geo</td>
<td>1296 MB</td>
</tr>
<tr>
<td>geo_hstore_hash_ops_idx</td>
<td>index</td>
<td>postgres</td>
<td>geo</td>
<td>925 MB</td>
</tr>
</tbody>
</table>

CREATE OPERATOR CLASS gin_hstore_bytea_ops FOR TYPE hstore

```
FUNCTION 1 byteacmp(bytea,bytea),
```

STORAGE bytea;

CREATE INDEX: 239 s Much faster comparison (no collation)

CREATE OPERATOR CLASS gin_hstore_ops FOR TYPE hstore

```
FUNCTION 1 bttextcmp(text,text),
```

STORAGE text;

CREATE INDEX: 2870 s
Hstore 9.3 vs 9.4

SUMMARY:

- 9.4 GIN posting list compression: indexes are smaller
- 9.4 GIN is smart regarding 'freq & rare' queries: time (freq & rare) ~ time (rare) instead of time (freq & rare) ~ time (freq)
- gin_hstore_hash_ops is good on 9.3 & 9.4 and faster default gin opclass
- Use gin_hstore_bytea_ops instead of default gin_hstore_ops — much faster create index

Get hstore_ops from:
from https://github.com/akorotkov/hstore_ops
Introduction to hstore

• Hstore benefits
  • In provides a flexible model for storing a semi-structured data in relational database
  • hstore has binary storage and rich set of operators and functions, indexes

• 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 is faster than json even on simple data

```sql
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!
Nested hstore

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 at PGCon-2013, Ottawa, Canada (May 24) — thanks Engine Yard for support!

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

• Binary storage for nested data at PGCon Europe — 2013, Dublin, Ireland (Oct 29)

Binary storage for nested data structures and application to hstore data type

• November, 2013 — binary storage was reworked, nested hstore and jsonb share the same storage. Andrew Dunstan joined the project.

• January, 2014 - binary storage moved to core
Nested hstore & jsonb

• Feb-Mar, 2014 - Peter Geoghegan joined the project, nested hstore was cancelled in favour to jsonb (Nested hstore patch for 9.3).

• Mar 23, 2014 Andrew Dunstan committed jsonb to 9.4 branch!

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 original 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
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
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
EXPLAIN ANALYZE SELECT count(*) FROM jb WHERE jb @> '{"tags": [{"term": "NYC"}]}':jsonb;

---

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

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
      (8 rows)

Jsonb ~ 150X faster Json
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
(8 rows)

Jsonb ~ 1800X faster Json
**MongoDB 2.6.0**

- **Load data - ~13 min**  **SLOW!**  
  
  `mongoimport --host localhost -c js --type json < delicious-rss-1250k`

  2014-04-08T22:47:10.014+0400

  ...  

  2014-04-08T23:00:36.050+0400

  2014-04-08T23:00:36.565+0400 check 9 1252973

  2014-04-08T23:00:36.566+0400 imported 1252973 objects

  
  `mongoimport` takes ~13 minutes for ~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
Jsonb (Apr, 2014)

- Documentation
  - JSON Types, JSON Functions and Operators

- There are many functionality left in nested hstore
  - Can be an extension

- Need query language for jsonb
  - <,>,&& ... operators for values
    a.b.c.d && [1,2,10]
  - Structural queries on paths
    *.d && [1,2,10]
  - Indexes!
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 HINT value_expr
| NOT expr
| NOT HINT value_expr
| NOT value Expr
| path '(' expr ')'
| '(' expr ')'#key ::= '*'
| '#'
| '%$'
| '$'
| STRING

value_expr ::= '=' scalar_value
| IN '(' value_list ')
| '=' array
| '=' '*'
| '<' NUMERIC
| '<' '=' NUMERIC
| '>' NUMERIC
| '>' '=' NUMERIC
| '@' '>' array
| '<' '@' array
| '&' '&' array
| IS ARRAY
| IS NUMERIC
| IS OBJECT
| IS STRING
| IS BOOLEAN

path ::= key
| path '.' key_any
| NOT '.' key_any

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

key_any ::= key
| NOT

value_list ::= scalar_value
| value_list ',' scalar_value

array ::= '[' value_list ']

scalar_value ::= null
| STRING
| true
| false
| NUMERIC
| OBJECT

.......
Jsonb query language (Jsquery)

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

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

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

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

- Use "double quotes" for key
  ```sql
  select 'a1."12222" < 111'::jsquery;
  ```

```
path ::= key
| path "." key_any
| NOT "." key_any

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

key_any ::= key
| NOT
```

---

path ::= key
| path "." key_any
| NOT "." key_any

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

key ::= key
| NOT
Jsonb query language (Jsquery)

• Scalar

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

• Test for key existence

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

• Array overlap

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

• Array contains

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

• Array contained

```sql
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
| IS ARRAY
| IS NUMERIC
| IS OBJECT
| IS STRING
| IS BOOLEAN
Jsonb query language (Jsquery)

- Type checking

```sql
select '{"x": true}' @@ 'x IS boolean':jsquery,
     '{"x": 0.1}' @@ 'x IS numeric':jsquery;
?column? | ?column?
---------+---------
t      | t

select '{"a":{"a":1}}' @@ 'a IS object':jsquery;
?column?
-------
t

select '{"a":["xxx"]}' @@ 'a IS array':jsquery, '"xxx"' @@ '$ IS array':jsquery;
?column? | ?column?
---------+---------
t      | t

declare IS BOOLEAN
declare IS NUMERIC
declare IS ARRAY
declare IS OBJECT
declare IS STRING
```
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"] AND product_sales_rank($ > 10000 AND $ < 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
    
    \[
    \{"a":{"b":{"c":10}}\} \rightarrow 10. (\text{bloom}(a) \text{ or } \text{bloom}(b) \text{ or } \text{bloom}(c))
    \]

    - Good for key matching (wildcard support), not good for range query
  
  - `jsonb_path_value_ops` — hash path (like `jsonb_path_ops`)
    
    \[
    \{"a":{"b":{"c":10}}\} \rightarrow \text{hash}(a.b.c).10
    \]

    - No wildcard support, no problem with ranges

---

### List of relations

<table>
<thead>
<tr>
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<th>Name</th>
<th>Type</th>
<th>Owner</th>
<th>Table</th>
<th>Size</th>
<th>Description</th>
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<td>postgres</td>
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<td>index</td>
<td>postgres</td>
<td>jb</td>
<td>251 MB</td>
<td></td>
</tr>
</tbody>
</table>
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
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" 
  AND product_sales_rank( $ > 10000 AND $ < 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)

• If we rewrite query and use planner

```sql
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  Potentially, query could be faster Mongo!
```

(9 rows)
Jsquery (optimiser) — NEW!

- Jsquery now has built-in optimiser for simple queries.

```sql
explain (analyze, costs off) select count(*) from jr where jr @@ 'similar_product_ids && \"B000089778\"' AND product_sales_rank( $ > 10000 AND $ < 20000)
```

Aggregation:

```
Aggregate (actual time=0.422..0.422 rows=1 loops=1)
  -> Bitmap Heap Scan on jr (actual time=0.099..0.416 rows=45 loops=1)
      Recheck Cond: (jr @@ '\"similar_product_ids\" && \"B000089778\"\n"product_sales_rank\"($ > 10000 AND $ < 20000))':jsquery)
      Rows Removed by Index Recheck: 140
      Heap Blocks: exact=107
  -> Bitmap Index Scan on jr_path_value_idx (actual time=0.060..0.060 rows=185 loops=1)
      Index Cond: (jr @@ '\"similar_product_ids\" && \"B000089778\"\n"product_sales_rank\"($ > 10000 AND $ < 20000))':jsquery)
```

Execution time: **0.480 ms vs 7 ms MongoDB!**
Jsquery (optimiser) — NEW!

- Jsquery now has built-in optimiser for simple queries.
  Analyze query tree and push non-selective parts to recheck (like filter)

Selectivity classes:
1) Equality (x = c)
2) Range (c1 < x < c2)
3) Inequality (c > c1)
4) Is (x is type)
5) Any (x = *)

```
SELECT gin_debug_query_path_value('similar_product_ids && ["B000089778"]
    AND product_sales_rank( $ > 10000 AND $ < 20000)');

gin_debug_query_path_value
--------------------------------------
similar_product_ids.# = "B000089778" , entry 0 +
```
Jsquery (optimiser) — NEW!

- Jsquery optimiser pushes non-selective operators to recheck

```sql
explain (analyze, costs off) select count(*) from jr where jr @@ 'similar_product_ids && ['B000089778'] AND product_sales_rank( $ > 10000 AND $ < 20000)'
```

```
Aggregate (actual time=0.422..0.422 rows=1 loops=1)
  -> Bitmap Heap Scan on jr (actual time=0.099..0.416 rows=45 loops=1)
    Recheck Cond: (jr @@ '("similar_product_ids" && ['B000089778']) AND "product_sales_rank"($ > 10000 AND $ < 20000))':jsquery)
  Rows Removed by Index Recheck: 140
  Heap Blocks: exact=107
  -> Bitmap Index Scan on jr_path_value_idx (actual time=0.060..0.060 rows=185 loops=1)
    Index Cond: (jr @@ '("similar_product_ids" && ['B000089778']) AND "product_sales_rank"($ > 10000 AND $ < 20000))':jsquery)
Execution time: 0.480 ms
```
Jsquery (HINTING) — NEW!

• Jsquery now has HINTING (if you don't like optimiser!)

```sql
explain (analyze, costs off) select count(*) from jr where jr @@ 'product_sales_rank > 10000'
```

```
Aggregate (actual time=2507.410..2507.410 rows=1 loops=1)
  -> Bitmap Heap Scan on jr (actual time=1118.814..2352.286 rows=2373140 loops=1)
    Recheck Cond: (jr @@ "product_sales_rank" > 10000'::jsquery)
    Heap Blocks: exact=201209
  -> Bitmap Index Scan on jr_path_value_idx (actual time=1052.483..1052.488 rows=2373140 loops=1)
    Index Cond: (jr @@ "product_sales_rank" > 10000'::jsquery)
Execution time: 2524.951 ms
```

• Better not to use index — HINT /*--noindex */

```sql
explain (analyze, costs off) select count(*) from jr where jr @@ 'product_sales_rank > 10000'
```

```
Aggregate (actual time=1376.262..1376.262 rows=1 loops=1)
  -> Seq Scan on jr (actual time=0.013..1222.122 rows=2373140 loops=1)
    Filter: (jr @@ "product_sales_rank" /*--noindex */ > 10000'::jsquery)
    Rows Removed by Filter: 650022
Execution time: 1376.284 ms
```
Contrib/jsquery

• Jsquery index support is quite efficient (0.5 ms vs Mongo 7 ms!)

• Future direction
  • Make jsquery planner friendly
  • Need statistics for jsonb

• 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!
PostgreSQL 9.4+
- Open-source
- Relational database
- Strong support of json
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

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<tr>
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<th>Name</th>
<th>Type</th>
<th>Owner</th>
<th>Table</th>
<th>Size</th>
<th>Description</th>
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<td>jb</td>
<td>table</td>
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<td>598 MB</td>
<td>now much less!</td>
</tr>
</tbody>
</table>
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

**Generalized Inverted Index**

- An inverted index is an index structure storing a set of (key, posting list) pairs, where 'posting list' is a set of documents in which the key occurs.

- Generalized means that the index does not know which operation it accelerates. It works with custom strategies, defined for specific data types. GIN is similar to GiST and differs from B-Tree indices, which have predefined, comparison-based operations.
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

```json
{
    "product_group": "Book",
    "product_sales_rank": 15000
},
{
    "product_group": "Music",
    "product_sales_rank": 25000
}
```
CREATE INDEX ... USING VODKA

- Delicious bookmarks, mostly text data

```
set maintenance_work_mem = '1GB';
```

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Type</th>
<th>Owner</th>
<th>Table</th>
<th>Size</th>
<th>Description</th>
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<tbody>
<tr>
<td>public</td>
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(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';
```

<table>
<thead>
<tr>
<th>Schema</th>
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<td>jr_vodka_idx3</td>
<td>index</td>
<td>postgres</td>
<td>jr</td>
<td>240 MB</td>
<td>155714.777</td>
</tr>
<tr>
<td>public</td>
<td>jr_vodka_idx4</td>
<td>index</td>
<td>postgres</td>
<td>jr</td>
<td>211 MB</td>
<td>169440.130 new spgist</td>
</tr>
</tbody>
</table>

(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)
There are can be different flavors of Vodka
Find twirled spaghetti
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
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
Another view on VODKA

• VODKA CONNECTING INDEXES
  • composite index, which combines different access methods
  • Nested search trees
ご清聴ありがとうございました。
VODKA Optimized Dendriform Keys Array