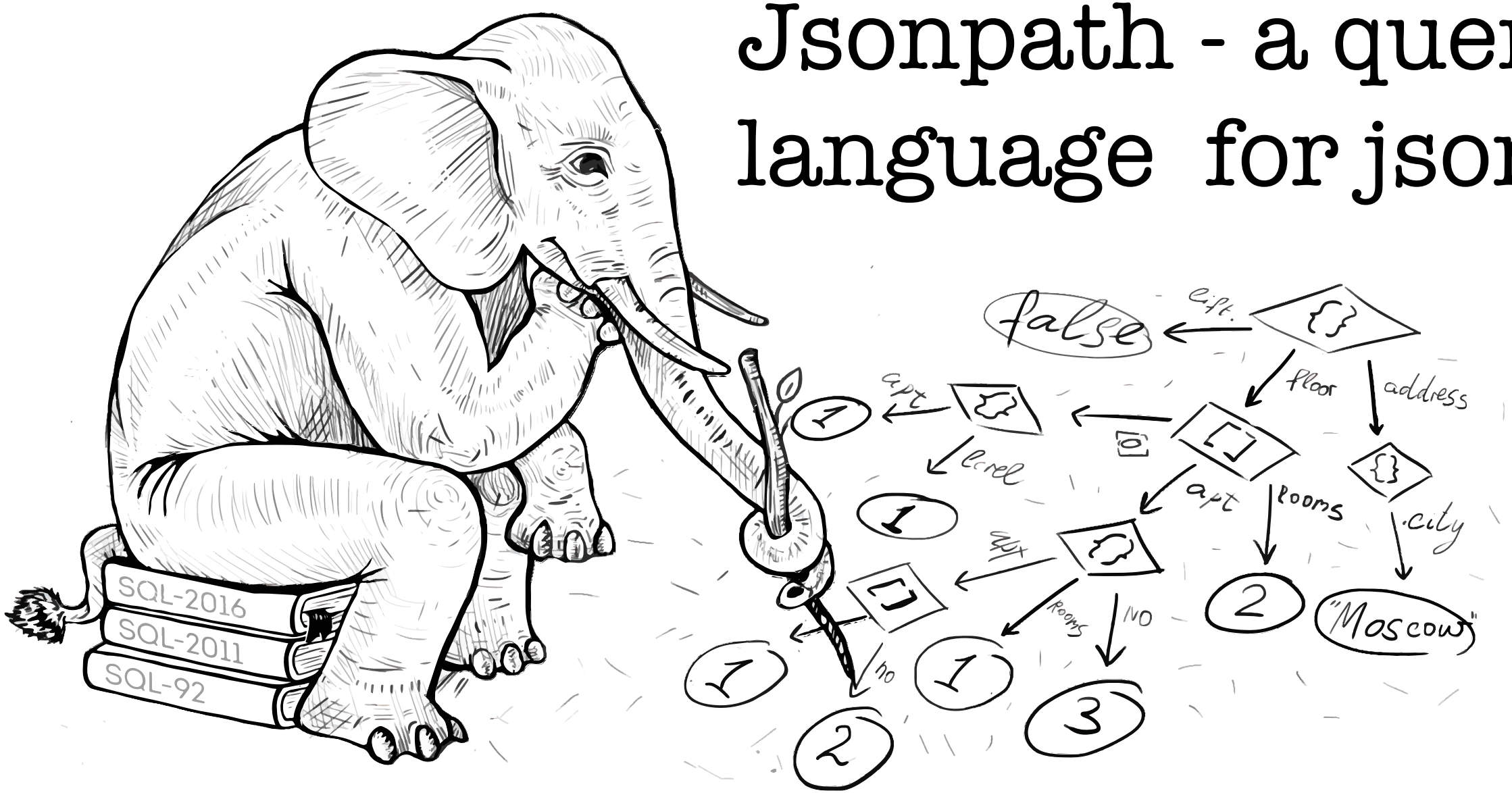
PGDAY.IT May 17, 2019

Jsonpath - a query language for json



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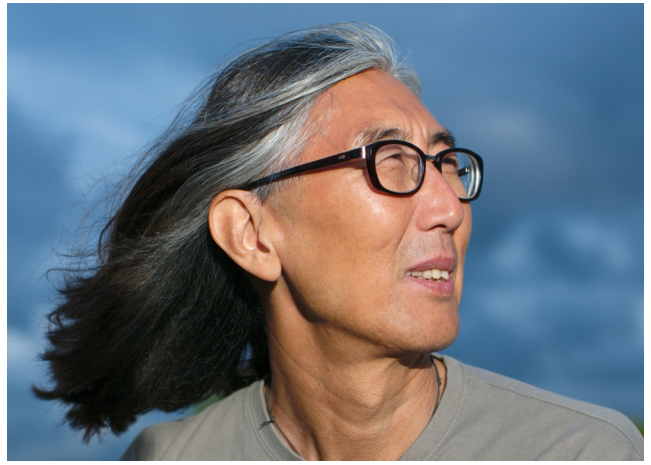
Postgres Professional



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Major PostgreSQL contributor

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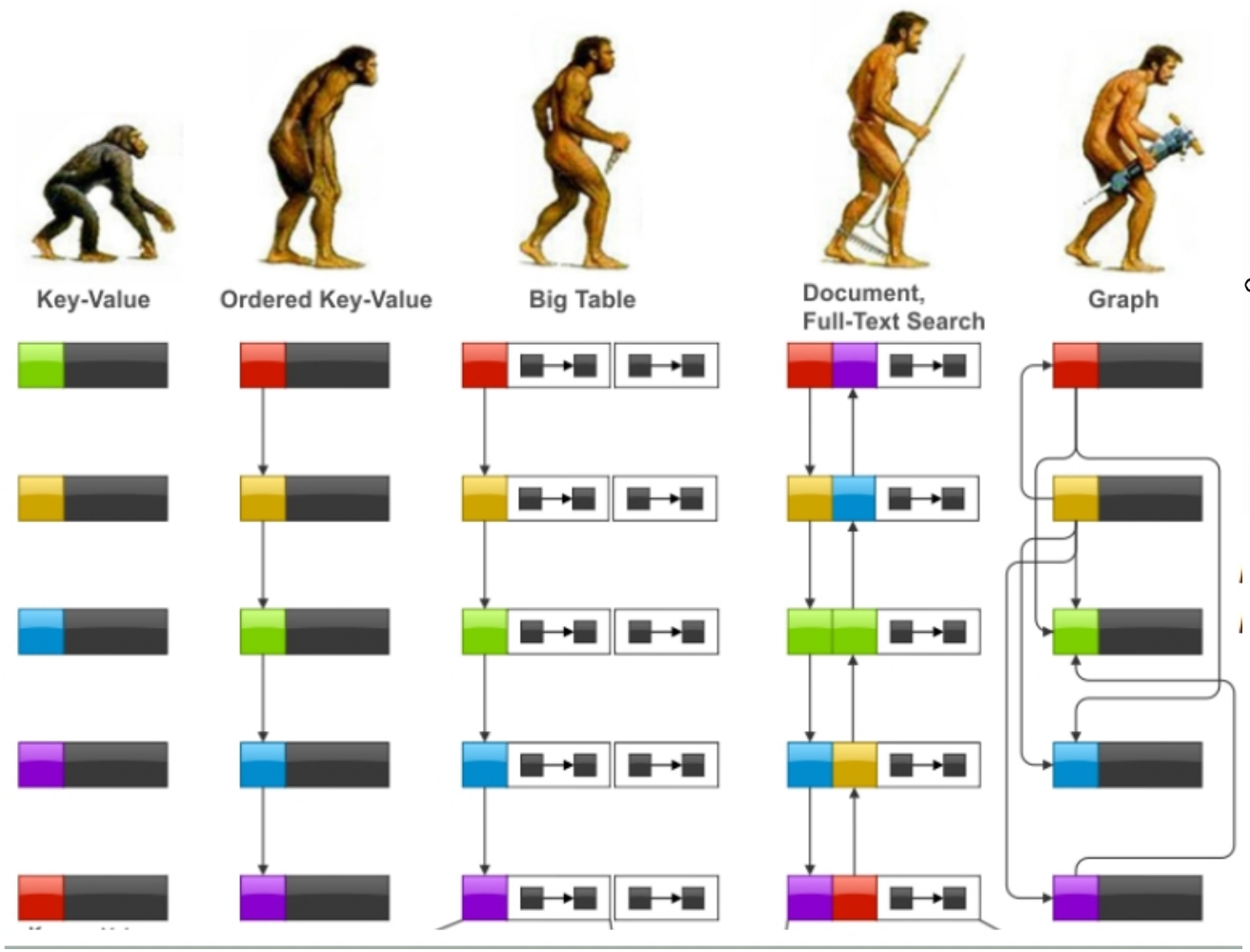
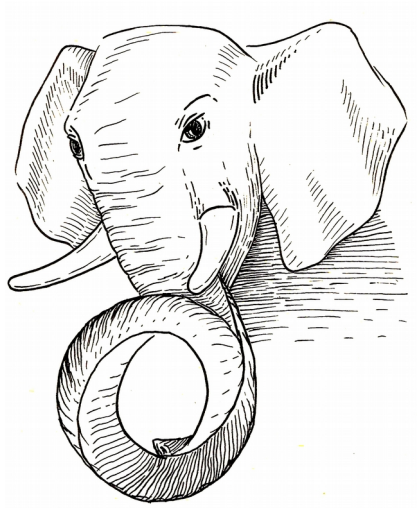
Since 1995

NOSQL POSTGRES IN SHORT





JSONPATH - 2019
- SQL/JSON — 2016
- Functions & operators
- Indexing

JSONB - 2014
- Binary storage
- Nesting objects & arrays
- Indexing

JSON - 2012
- Textual storage
- JSON verification

HSTORE - 2003
- Perl-like hash storage
- No nesting, no arrays
- Indexing

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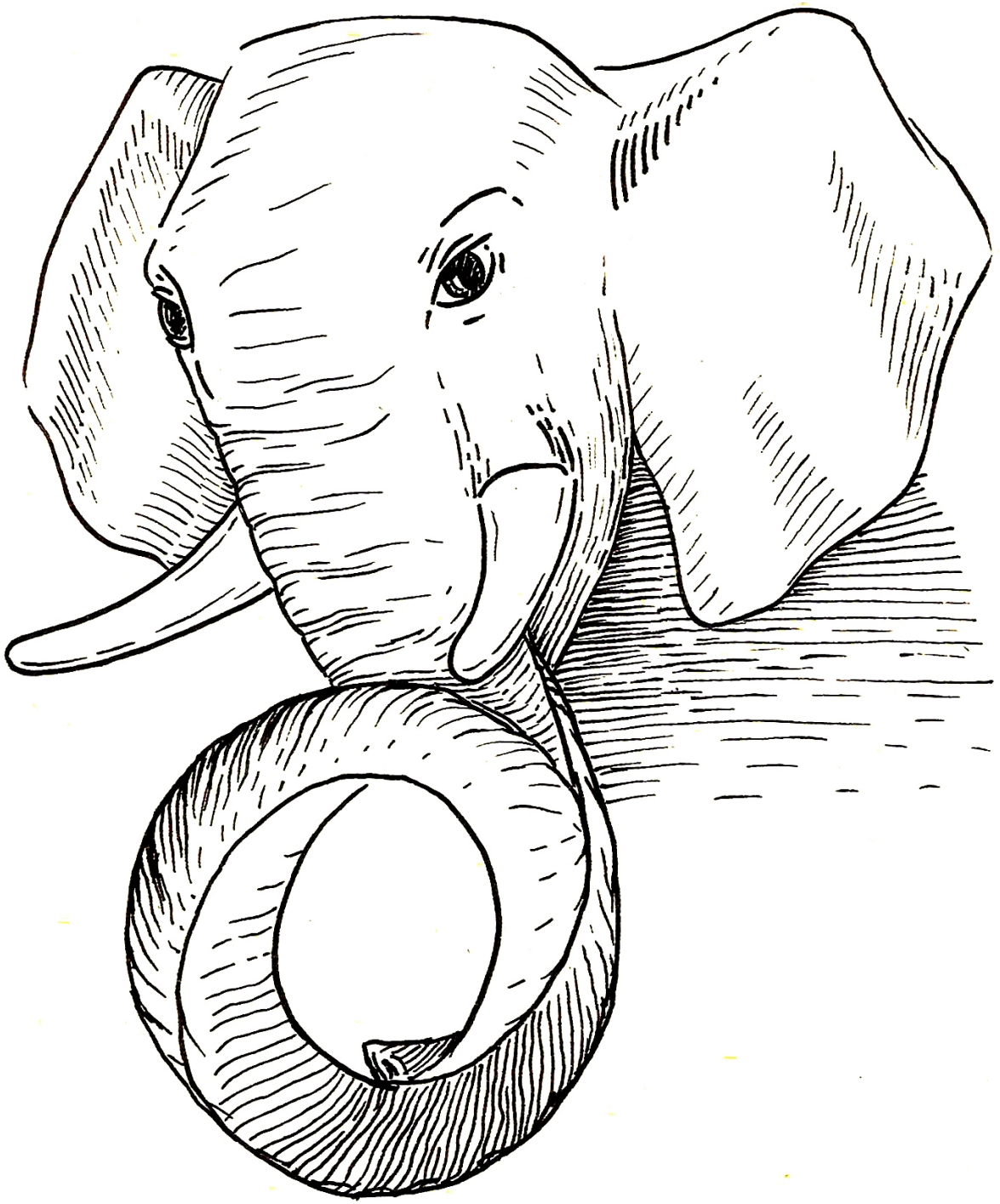
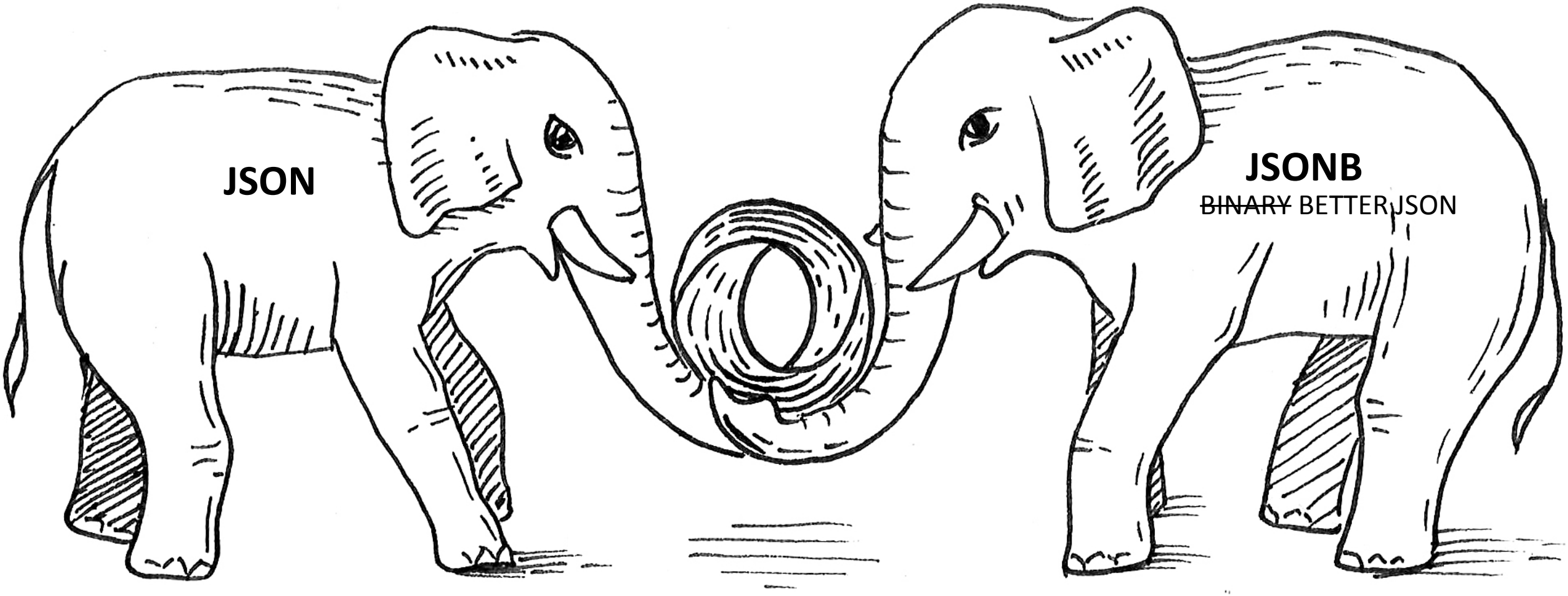


Json in PostgreSQL

(state of Art)

Two JSON data types !!!



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Jsonb vs Json

```
SELECT j::json AS json, j::jsonb AS jsonb FROM
(SELECT '{"cc":0, "aa":  2, "aa":1,"b":1}' AS j) AS foo;
                json                |           jsonb
------------------------------------+----------------------------
 {"cc":0, "aa":  2, "aa":1,"b":1} | {"b": 1, "aa": 1, "cc": 0}
(1 row)
```

- json: textual storage «as is»
- jsonb: binary storage, no need to parse, has index support
- jsonb: no whitespaces, no duplicated keys (last key win)
- jsonb: keys are sorted by (length, key)
- jsonb: a rich set of functions (\df jsonb*)
- jsonb: great performance, thanks to indexes: bult-in, jsquery

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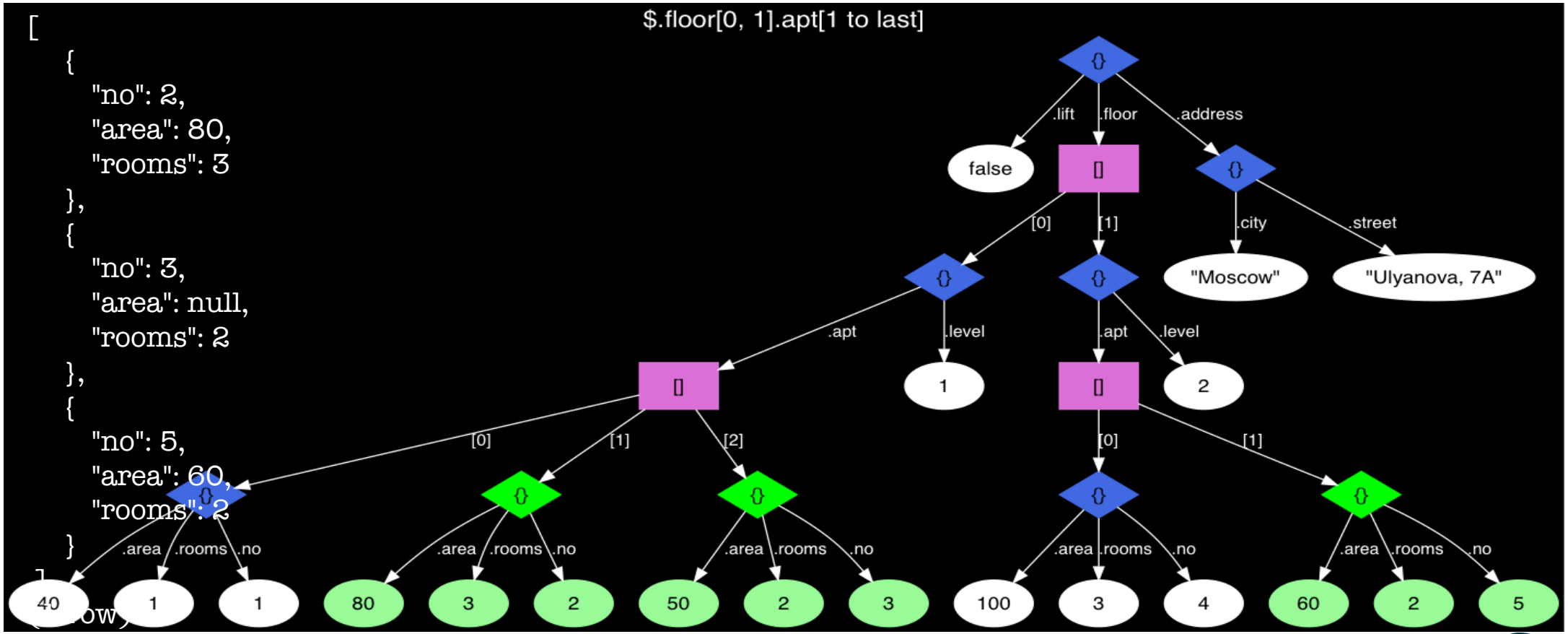
JSONB is GREAT, BUT

- JSONB is a «black box» for SQL, no good query language.



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JSONB is GREAT, BUT

- PG11 query (cumbersome)

```
SELECT jsonb_agg(apt)
FROM (SELECT apt->generate_series(1, jsonb_array_length(apt) - 1)
FROM (SELECT js->'floor'->unnest(array[0, 1])->'apt'
FROM house) apts(apt)) apts(apt);
```

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SQL/Foundation recognized JSON after 8 years

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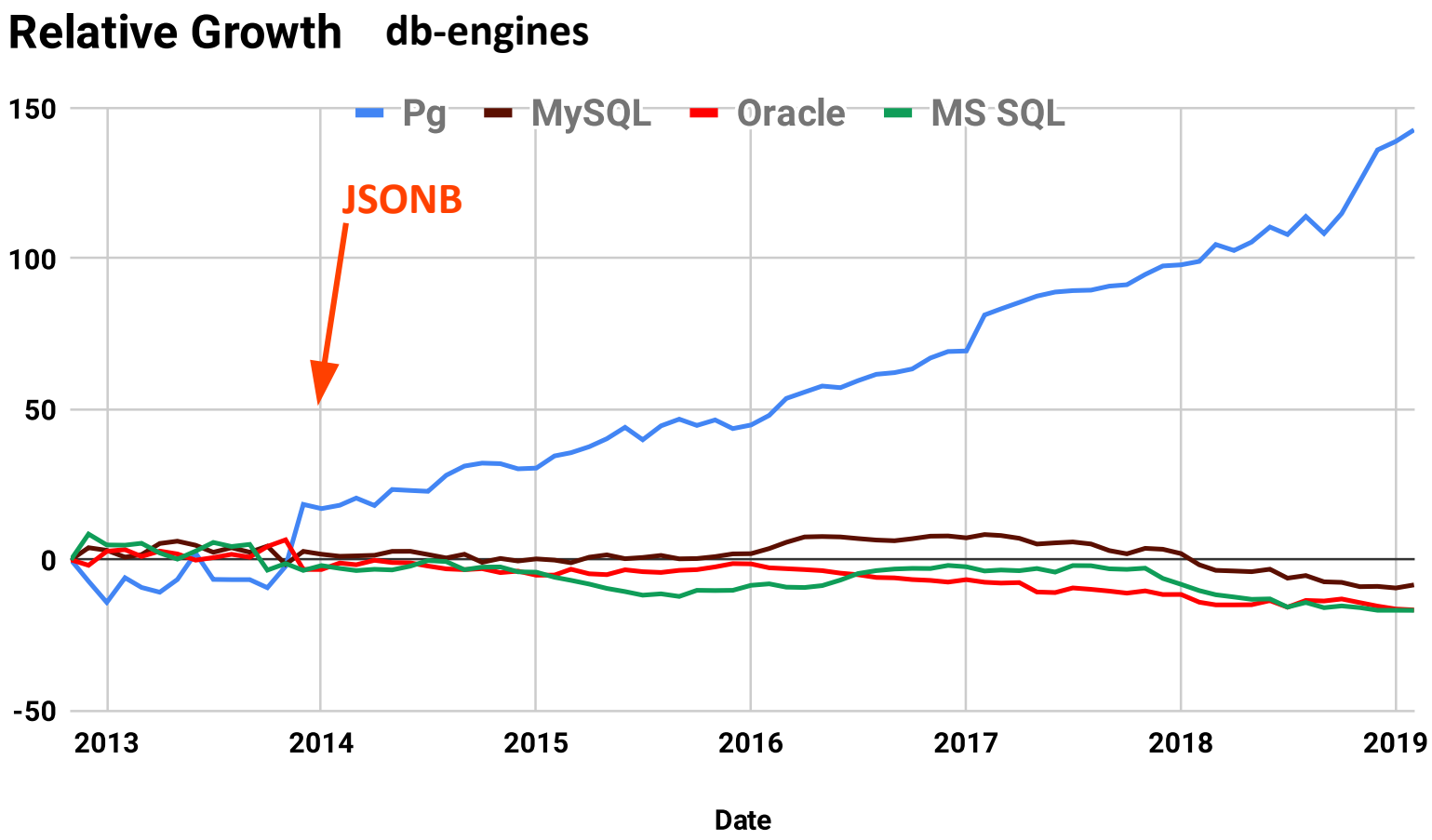
Postgres revolution: embracing relational databases

- NoSQL users attracted by the NoSQL Postgres features



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JSON Path query language — part of SQL/JSON

JON Path expression specify the parts of json, SQL-2016.

```
'$.floor[*].apt[*] ? (@.area > 40 && @.area < 90)'
```

- Dot notation used for member access – '$.a.b.c'
  $ - the current context element
  [*], [0 to LAST] - array access (starts from zero!)
- Filter(s) ? - '$.a.b.c ? (@.x > 10)'
  @ - current context in filter expression
- Methods - '$.a.b.c.x.type()'
  type(), size(), double(), ceiling(), floor(), abs(), keyvalue(), datetime()
- *lax* and *strict* modes to facilitate matching of the (sloppy) document structure and path expression

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JSON Path: [lax] vs strict

- Lax: missing keys ignored

```
SELECT jsonb '{"a":1}' @? 'lax $.b ? (@ > 1)';
 ?column?
----------
 f
```

- Strict: missing keys resulted null

```
SELECT jsonb '{"a":1}' @? 'strict $.b ? (@ > 1)';
 ?column?
----------
 (null)
```

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JSON Path: [lax] vs strict

- Lax: arrays unwrapped

```
SELECT jsonb '[1,2,[3,4,5]]' @? 'lax $[*] ? (@ == 5)';
 ?column?                        'lax $    ? (@ == 5)'
----------
 t
```

- Strict: requires an exact nesting

```
SELECT jsonb '[1,2,[3,4,5]]' @? 'strict $[*] ? (@[*] == 5)';
 ?column?
----------
 t
```

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JSON Path examples

- JSON Path expression is an optional path mode ``strict` or `lax` (default), followed by a path or unary/binary expression on paths. Path is a sequence of path elements, started from path variable, path literal or expression in parentheses and zero or more operators (JSON accessors, filters, and item methods).

'$' -- the whole JSON document (context item)
'$foo' -- variable "foo"
'"bar"' -- string literal
'12.345' -- numeric literal
'true' -- boolean literal
'null' -- null
'$.floor' -- field accessor on $
'$.floor[*]' -- the same, followed by wildcard array accessor

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JSON Path examples

- JSON Path expression is an optional path mode ``strict` or `lax` (default), followed by a path or unary/binary expression on paths. Path is a sequence of path elements, started from path variable, path literal or expression in parentheses and zero or more operators (JSON accessors, filters, and item methods).

```
-- complex path with filters and variables
'$.floor[*] ? (@.level < $max_level).apt[*] ? (@.area > $min_area).no'

-- arithmetic expressions:
'-$.a[*]' -- unary
'$.a + 3' -- binary
'2 * $.a - (3 / $.b + $x.y)' -- complex expression with variables
```

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JSON Path examples

- JSON Path expression is an optional path mode ``strict` or `lax` (default), followed by a path or unary/binary expression on paths. Path is a sequence of path elements, started from path variable, path literal or expression in parentheses and zero or more operators (JSON accessors, filters, and item methods).

```
-- parenthesized expression used as starting element of a path,
-- followed by two item methods ".abs()" and ".ceil()"
'($ + 1).abs().ceil()'

Syntactical errors in `jsonpath` are reported:
SELECT '$a. >1'::jsonpath;
ERROR:  bad jsonpath representation at character 8
DETAIL:  syntax error, unexpected GREATER_P at or near ">"
```

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JSON Path filter expression

- A filter expression is similar to a `WHERE` clause in SQL, it is used to remove SQL/JSON items from an SQL/JSON sequence if they do not satisfy a predicate.
- Syntax: ? (filter expression)
  - Variable @ - a reference the current SQL/JSON item in the SQL/JSON sequence.
- Predicates:
  - *exists*, test if a path expression has a non-empty result
  - Comparison predicates ==, !=, <>, <, <=, >, and >=
  - *like_regex* for string pattern matching.
    Optional *flag* can be combination of i, s (default), m, x.
  - *starts with* to test for an initial substring (prefix).
  - *is unknown* to test for *Unknown* results. Its operand should be in parentheses.

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JSON Path filters

- Arithmetic errors in filters suppressed:

```
-- behaviour required by standard

SELECT jsonb_path_query('[1,0,2]', '$[*] ? (1 / @ >= 1)');
jsonb_path_query
------------------
 1
(1 row)
```

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JSON Path methods

- Predefined methods attached to JSON Path expression

```
SELECT jsonb_path_query(jsonb '{"a":5, "b":2}','$ ? (@.a > 1).keyvalue()')
FROM house;
          jsonb_path_query
-----------------------------------
 {"id": 0, "key": "a", "value": 5}
 {"id": 0, "key": "b", "value": 2}
(2 rows)
```

- Methods can be combined

```
SELECT jsonb_path_query(jsonb '{"a":5, "b":2}','$ ? (@.a > 1).keyvalue().key')
FROM house;
 jsonb_path_query
------------------
 "a"
 "b"
(2 rows)
```

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JSON Path implementation in Postgres

- Standard permits only string literals in JSON Path specification.
- Json Path in Postgres implemented as jsonpath data type - the binary representation of parsed SQL/JSON path expression.
- To accelerate JSON Path queries using **existing** indexes for jsonb we need boolean operators for json[b] and jsonpath.
- Implementation as a type is much easier than integration of JSON path processing with executor (complication of grammar and executor).
- In simple cases, expressions with operators can be more concise than with SQL/JSON functions.
- It is Postgres way to use operators with custom query types (tsquery for FTS, lquery for ltree, jsquery for jsonb,...)

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jsonpath functions

- **`jsonb_path_exists()`** => boolean
  Test whether a JSON path expression returns any SQL/JSON items (operator @?).
- **`jsonb_path_match()`** => boolean
  Evaluate JSON path predicate (operator @@).
- **`jsonb_path_query()`** => setof jsonb
  Extract a sequence of SQL/JSON items from a JSON value.
- **`jsonb_path_query_array()`** => jsonb
- Extract a sequence of SQL/JSON items wrapped into JSON array.
- **`jsonb_path_query_first()`** => jsonb

  Extract the first SQL/JSON item from a JSON value.

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Jsonpath functions

- All `jsonb_path_xxx()` functions have the same signature:

```
jsonb_path_xxx(
    js jsonb,
    jsp jsonpath,
    vars jsonb DEFAULT '{}',
    silent boolean DEFAULT false
)
```

- "vars" is a jsonb object used for passing jsonpath variables:

```
SELECT jsonb_path_query_array('[1,2,3,4,5]', '$[*] ? (@ > $x)',
                              vars => '{"x": 2}');
 jsonb_path_query_array
------------------------
 [3, 4, 5]
```

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Jsonpath functions

- "silent" flag enables suppression of errors:

```
SELECT jsonb_path_query('[]', 'strict $.a');
ERROR:  SQL/JSON member not found
DETAIL:  jsonpath member accessor can only be applied to an object

SELECT jsonb_path_query('[]', 'strict $.a', silent => true);
 jsonb_path_query
------------------
(0 rows)
```

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Jsonpath functions: Examples

- ```
  jsonb_path_exists('{"a": 1}', '$.a') => true
  jsonb_path_exists('{"a": 1}', '$.b') => false
  ```

- ```
  jsonb_path_match('{"a": 1}', '$.a == 1') => true
  jsonb_path_match('{"a": 1}', '$.a >= 2') => false
  ```

- ```
  jsonb_path_query('{"a": [1,2,3,4,5]}',
                   '$.a[*] ? (@ > 2)') => 3, 4, 5 (3 rows)

  jsonb_path_query('{"a": [1,2,3,4,5]}',
                   '$.a[*] ? (@ > 5)') =>  (0 rows)
  ```

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  ```

Jsonpath functions: Examples

- ```
  jsonb_path_query_array('{"a": [1,2,3,4,5]}',
                         '$.a[*] ? (@ > 2)') => [3, 4, 5]

  jsonb_path_query_array('{"a": [1,2,3,4,5]}',
                         '$.a[*] ? (@ > 5)') => []
  ```
- ```
  jsonb_path_query_first('{"a": [1,2,3,4,5]}',
                         '$.a[*] ? (@ > 2)') => 3

  jsonb_path_query_first('{"a": [1,2,3,4,5]}',
                         '$.a[*] ? (@ > 5)') => NULL
  ```

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Jsonpath: boolean operators for jsonb

- `jsonb @? jsonpath` (exists)
  Test whether a JSON path expression returns any SQL/JSON items.

```
jsonb '[1,2,3]' @? '$[*] ? (@ == 3)'   => true
```

- `jsonb @@ jsonpath` (match)
  Get the result of a JSON path predicate.

```
jsonb '[1,2,3]' @@ '$[*] == 3'   => true
```

- Operators are interchangeable:

```
js @? '$.a'       <=>  js @@ 'exists($.a)'
js @@ '$.a == 1' <=>  js @? '$ ? ($.a == 1)'
```

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Example: Two floors building

```
{
  "info": {
    "contacts": "Postgres Professional\n+7 (495) 150-06-91\
ninfo@postgrespro.ru",
    "dates": ["01-02-2015", "04-10-1957 19:28:34 +00", "12-04-1961 09:07:00
+03"]
  },
  "address": {
    "country": "Russia",
    "city": "Moscow",
    "street": "117036, Dmitriya Ulyanova, 7A"
  },
  "lift": false,
  "floor": [
    {
      "level": 1,
      "apt": [
        {"no": 1, "area": 40, "rooms": 1},
        {"no": 2, "area": 80, "rooms": 3},
        {"no": 3, "area": null, "rooms": 2}
      ]
    },
    {
      "level": 2,
      "apt": [
        {"no": 4, "area": 100, "rooms": 3},
        {"no": 5, "area": 60, "rooms": 2}
      ]
    }
  ]
}
```

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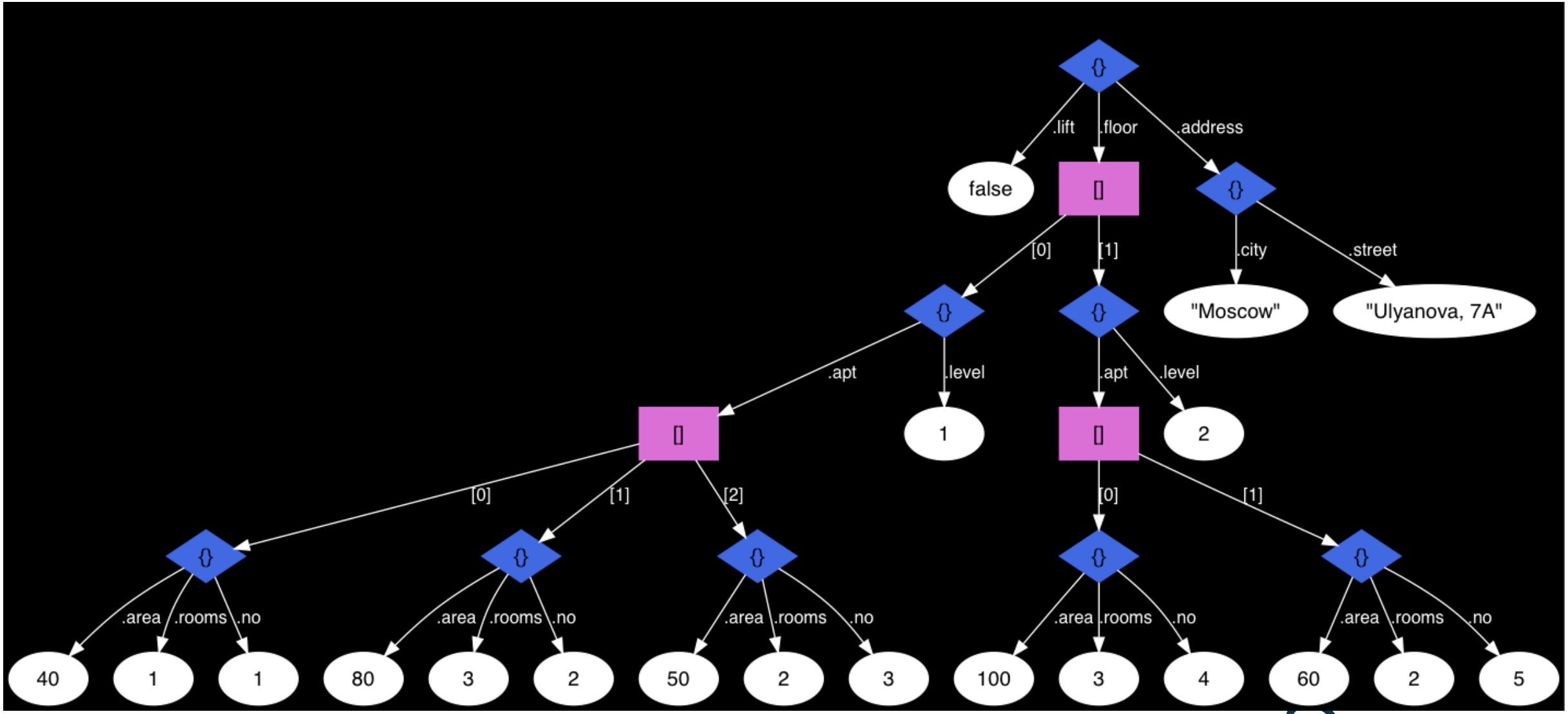
2-floors house



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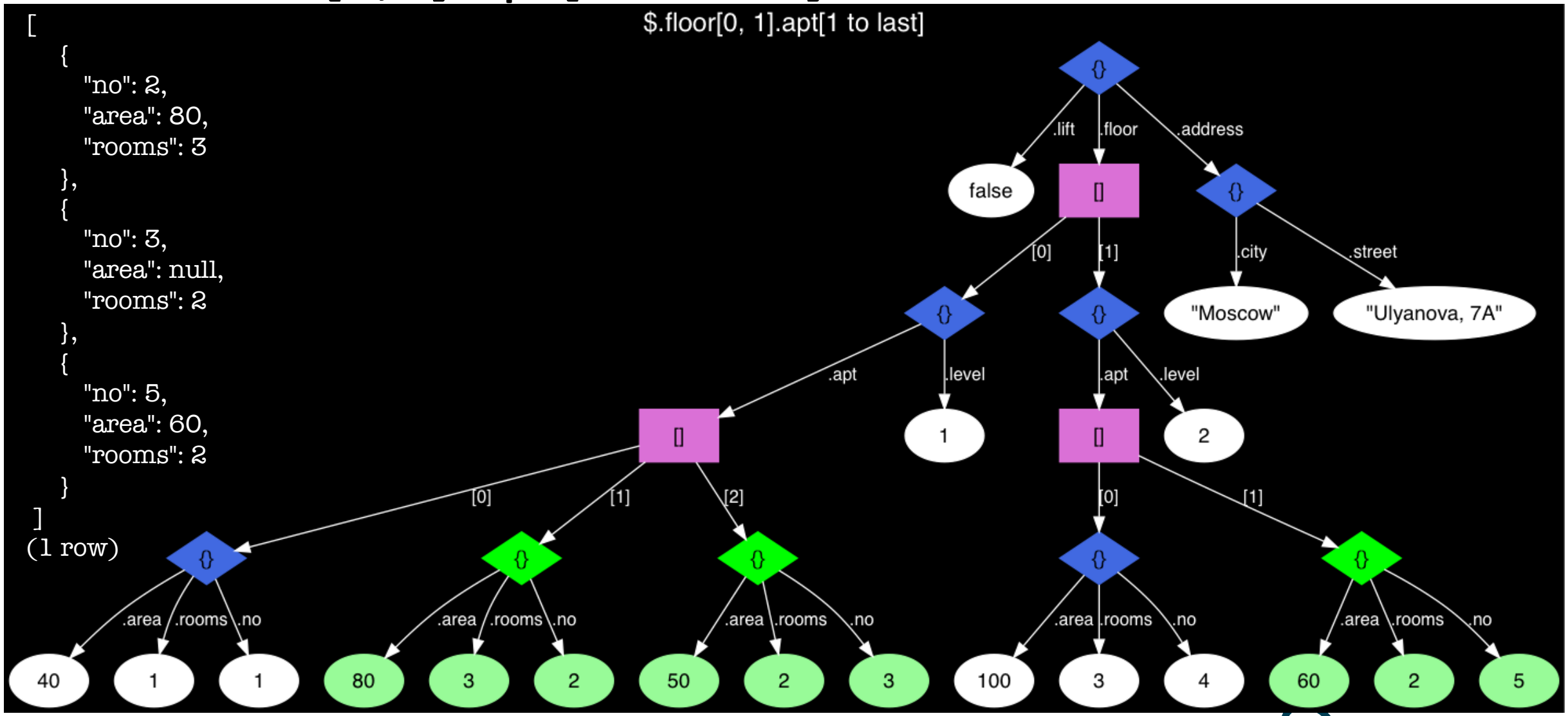
$.floor[0,1].apt[1 to last]



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$.floor[0, 1].apt[1 to last]

- PG12 (jsonpath) query

```
SELECT jsonb_path_query_array(js, '$.floor[0, 1].apt[1 to last]')
FROM house;
```

- PG11 query

```
SELECT jsonb_agg(apt)
FROM (SELECT apt->generate_series(1, jsonb_array_length(apt) - 1)
FROM (SELECT js->'floor'->unnest(array[0, 1])->'apt'
FROM house) apts(apt)) apts(apt);
```

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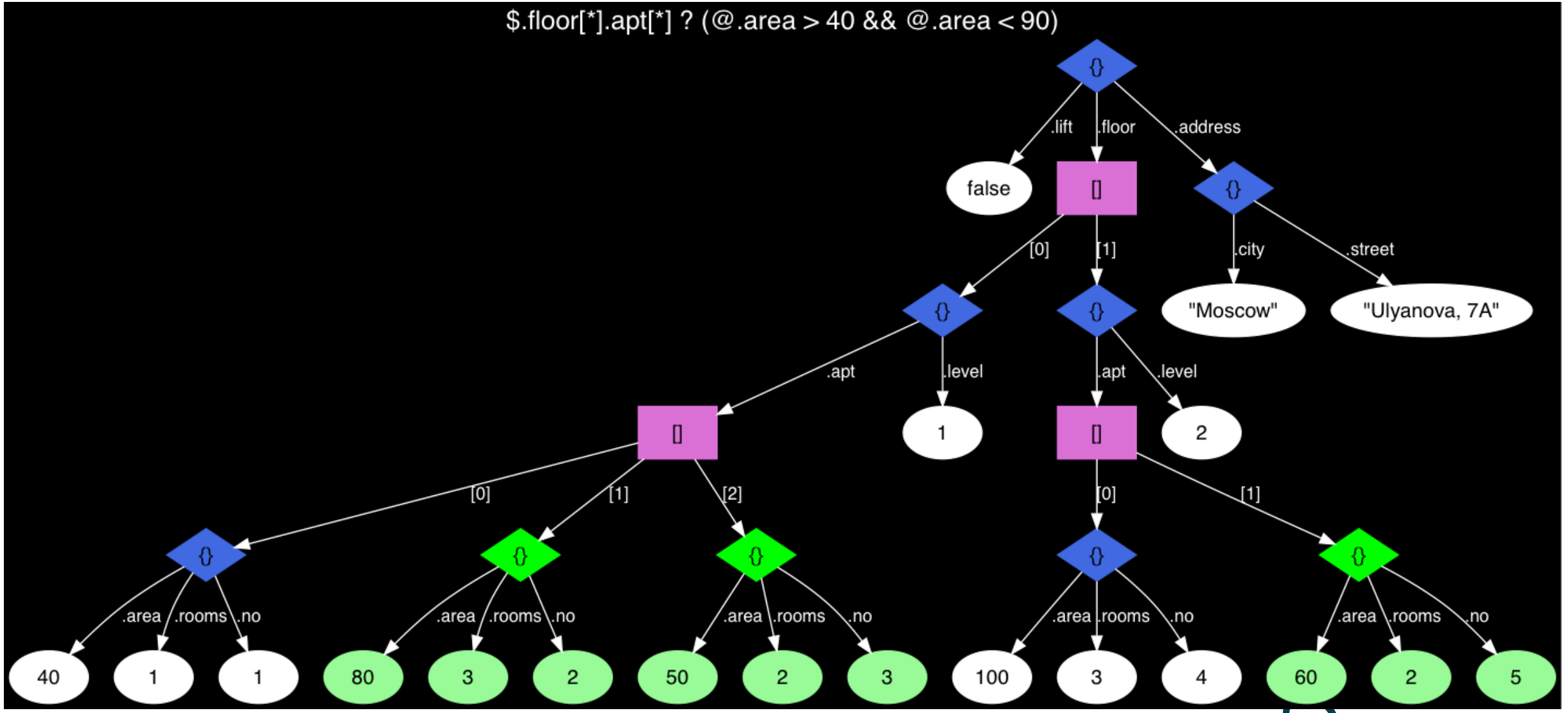
$.floor[*].apt[*] ? (@.area > 40 && @.area < 90)



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$.floor[*].apt[*] ? (@.area > 40 && @.area < 90)

- PG12 (jsonpath) query

```
SELECT jsonb_path_query(js,'$.floor[*].apt[*] ?
                           (@.area > 40 && @.area < 90)')
FROM house;
```

- PG11 query

```
SELECT apt
FROM (SELECT jsonb_array_elements(jsonb_array_elements(js->'floor')->'apt')
      FROM house) apts(apt)
WHERE (apt->>'area')::int > 40 AND (apt->>'area')::int < 90;
```

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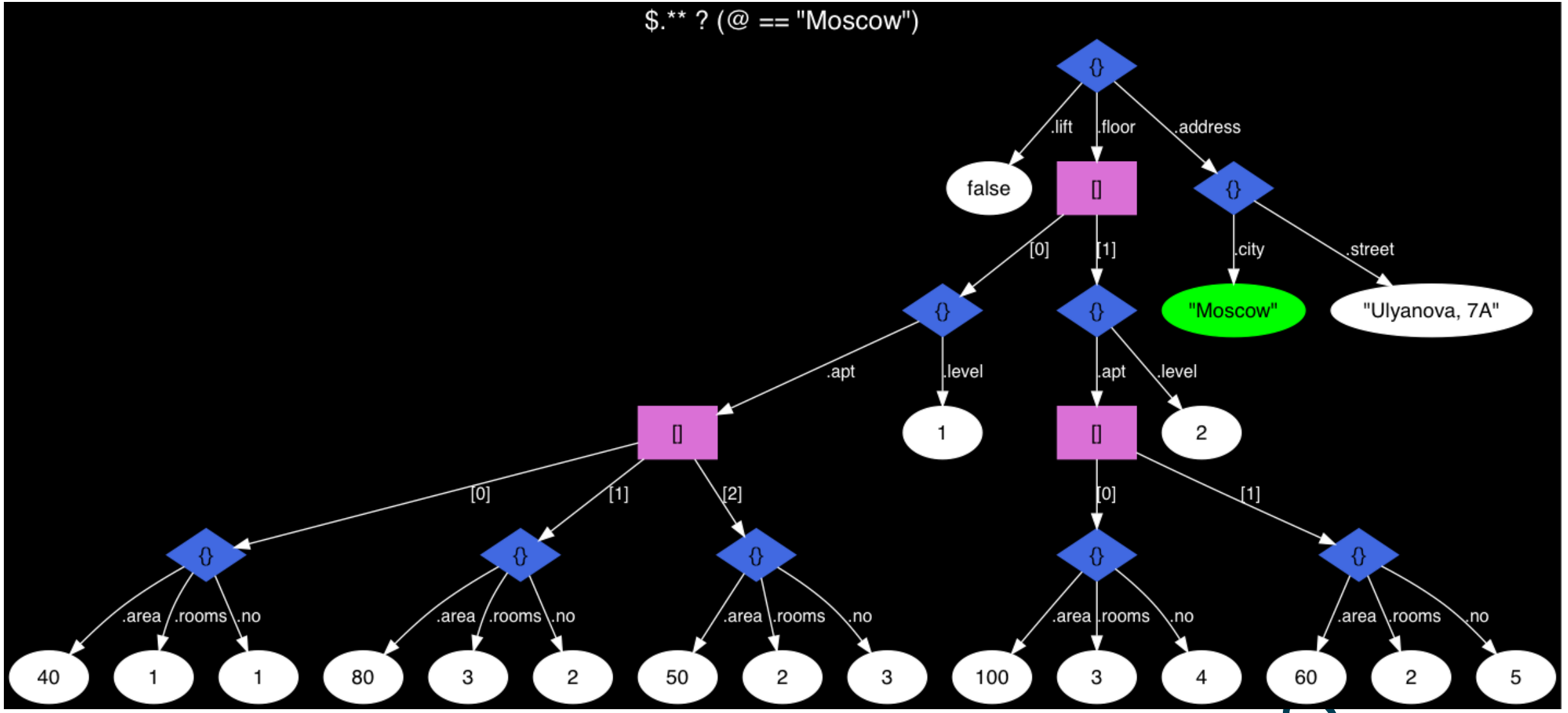
Extension: $.** ? (@ == "Moscow")



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Extension: $.** ? (@ == "Moscow")

- PG12 (jsonpath wildcard) query

```
SELECT jsonb_path_exists(js, '$.** ? (@ == "Moscow")') FROM house;
SELECT jsonb_path_exists(js, '$.**{0 to last} ? (@ == "Moscow")') FROM house;
```

- JSQUERY query

https://github.com/postgrespro/jsquery

```
SELECT
js @@  '* = "Moscow"'::jsquery
FROM house.
```

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Extension: $.** ? (@ == "Moscow")

- PG11 query

```
WITH RECURSIVE t(value) AS
  (SELECT * FROM house
   UNION ALL
    ( SELECT
        COALESCE(kv.value, e.value) AS value
      FROM
        t
      LEFT JOIN LATERAL jsonb_each(
        CASE WHEN jsonb_typeof(t.value) = 'object' THEN t.value ELSE NULL END
      ) kv ON true
      LEFT JOIN LATERAL jsonb_array_elements(
        CASE WHEN jsonb_typeof(t.value) = 'array' THEN t.value ELSE NULL END
      ) e ON true
      WHERE
        kv.value IS NOT NULL OR e.value IS NOT NULL)
  )
SELECT EXISTS (SELECT 1 FROM t WHERE value = '"Moscow"');
```

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JSON Path in PG12: one missing feature

- `.datetime()` item method not supported in PG12:

```
-- behavior required by standard
SELECT jsonb_path_query('"13.03.2019"',
'$.datetime("DD.MM.YYYY")');
 jsonb_path_query
------------------
 "2019-03-13"
(1 row)

-- behavior of PG12
SELECT jsonb_path_query('"13.03.2019"',
'$.datetime("DD.MM.YYYY")');
ERROR:  bad jsonpath representation
```

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SQL/JSON standard conformance

SQL/JSON feature	PostgreSQL 12	Oracle 18c	MySQL 8.0.4	SQL Server 2017
JSON PATH: 15	14/15	11/15	5/15	2/15

PostgreSQL 12 has **the best implementation** of JSON Path

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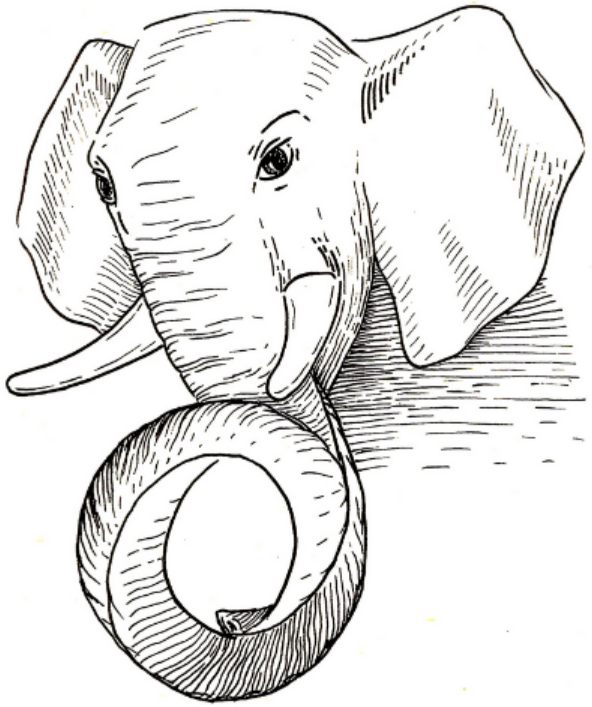
More information about Jsonpath

https://github.com/obartunov/sqljsondoc/blob/master/jsonpath.md

Gentle Guide to JSONPATH in PostgreSQL



This document describes SQL/JSON implementation as committed to PostgreSQL 12, which consists of implementation of JSON Path - the JSON query language, and several functions and operators, which use the path language to work with jsonb data. Consider this document as a tutorial , the reference guide is available as a part of offical PostgreSQL documentation for release 12.

Authors: Oleg Bartunov and Nikita Glukhov.

Introduction to SQL/JSON

SQL-2016 standard doesn't describes the JSON data type, but instead it introduced SQL/JSON data model (not JSON data type like XML) with string storage and path language used by certain SQL/JSON functions to query JSON. SQL/JSON data model is a sequences of items, each of which is consists of SQL scalar values with an additional SQL/JSON null value, and composite data structures using JSON arrays and objects.

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JSONB indexing: built-in opclasses

```
Sample jsonb: {"k1": "v1", "k2": ["v2", "v3"]}
```

- **`jsonb_ops`** (default GIN opclass for jsonb) extracts keys and values
  - "k1", "k2", "v1", "v2", "v3"
  - Supports top-level key-exists operators ?, ?& and ?| , contains @> operator
  - Overlapping of large postings might be slow
- **jsonb_hash_ops** extracts hashes of paths:
  - hash("k1"."v1"), hash("k2".#."v2"), hash("k2".#."v3")
  - Supports only contains @> operator
  - Much faster and smaller than default opclass (for @>)

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JSONB indexing: Jsquery extension

- jsonb_path_value_ops
  - (hash(full_path);value)
  - exact and range queries on values, exact path searches
- jsonb_laxpath_value_ops (branch sqljson)
  - The same as above, but array path items are ignored, which greatly simplifies extraction of ***lax*** JSON path queries.
- jsonb_value_path_ops
  - (value; bloom(path_1) | bloom(path_2) | … bloom(path_N))
  - Exact value search and wildcard path queries.
- Also, jsquery provides debugging and query optimizer with hints.

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Jsonpath performance (simple queries)

- Test table with 3 mln rows

```
CREATE TABLE t AS
SELECT jsonb_build_object('x', jsonb_build_object('y', jsonb_build_object('z', i::text)))
FROM generate_series(1, 3000000) i;

SELECT * from t where jsonb_path_query_first(js, '$.x.y.z') = '"123"';
            js
--------------------------
 {"x": {"y": {"z": "123"}}}
(1 row)
```

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Jsonpath performance (simple queries)

- Performance of arrow operators is slightly better for simple queries, but jsonpath allows more complex queries (see intra joins example).

query	time, ms	
jsonb_path_query_first(js, '$.x.y.z') = '"123"'	1700	
js->'x'->'y'->'z' = '"123"'	1700	
jsonb_path_query_first(js, '$.x.y.z')->>0 = '123'	600	
js->'x'->'y'->>'z' = '123'	430	
jsonb_path_exists(js, '$? ($.x.y.z == "123")')	1000	
jsonb_path_match(js, '$.x.y.z == "123"')	1000	
jsonb_path_match(js, '$.x.y.z == $x', '{"x": "123"}')	1100	
jsonb_path_match(js, '$.x.y.z == $x', jsonb_object(array['x'], array['123']))	1100	immutable
jsonb_path_match(js, '$.x.y.z == $x', jsonb_build_object('x', '123'))	2800	stable
jsonb_extract_path(js, 'x', 'y', 'z') = '"123"'	1670	
jsonb_extract_path_text(js, 'x', 'y', 'z') = '123'	580	

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Jsonpath operators: joins

- Find all authors with the same bookmarks as the given author

```
CREATE index ON bookmarks USING gin(jb  jsonb_path_ops );

SELECT
  b1.jb->'author'
FROM
  bookmarks b1,
  bookmarks b2
WHERE
  b1.jb @@ format('$.title == %s && $.author != %s', b2.jb -> 'title', b2.jb -> 'author')::jsonpath
AND  b2.jb @@ '$.author == "ant.on"'::jsonpath;
```

Seq scan: 35000 ms, Index scan: 6 ms

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Jsonpath intra joins (joining parts of the same column)

Query: find all the actors && editors in **the same movie** (43808 out of 6378007 rows in names). Actress && editors — 7173.

- **Jsonpath**:

```
SELECT jb->'id' FROM names
WHERE jb @@ '$.roles[*] ? (@.role == "actor").title ==
             $.roles[*] ? (@.role == "editor").title'::jsonpath;
```

  Sequential Scan: **29748.223 ms**
  Sequential Scan (parallel): **4678.925 ms**
  Bitmap Index Scan (`jsquery index`): **2328.880 ms**

```
"id": ....
"roles": [
        {
         "role": "actor",
         "title": ....
        }
       ...
        {}
       ]
```

- **«Old» way:**

```
SELECT jb->'id' FROM names WHERE
jb @> '{"roles": [{"role": "actor"}, {"role": "editor"}]}' AND
(SELECT array_agg(r->>'title') FROM jsonb_array_elements(jb->'roles') roles(r)
 WHERE r->>'role' = 'actor') &&
(SELECT array_agg(r->>'title') FROM jsonb_array_elements(jb->'roles') roles(r)
 WHERE r->>'role' = 'editor');
```

Sequential scan: **20233.032** ms
Bitmap Index Scan: **3860.534** ms

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Jsonpath intra joins (joining parts of the same column)

Jsonpath version is the fastest, since it has its own executor, no overheads.

- Performance summary

jsonpath:

```
Sequential Scan:                29748.223 ms
Sequential Scan (parallel):      4678.925 ms
Bitmap Index Scan (jsquery index):  2328.880 ms
```

- **«Old» way:**

Arrow (old way):

```
Sequential scan:                20233.032 ms
Bitmap Index Scan:                3860.534  ms
```

Relational way:

```
Sequential Scan:                34840.434 ms
Sequential Scan (parallel,6):    4233.829 ms
Bitmap Index Scan:              34454.714 ms
Bitmap Index Scan(parallel,6):   3807.380 ms
```

Mongo: **5000 ms**

```
"id": ....
"roles": [
        {
         "role": "actor",
         "title": ....
        }
       ...
        {}
       ]
```

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Roadmap

- PG13: SQL/JSON functions from SQL-2016 standard
- PG13: datetime support in JSON Path
- PG13: Planner support functions
- PG13: Parameters for opclasses - jsonpath to specify parts of jsonb to index
- PG13: Jsquery GIN opclasses to core
- PG13: Extend jsonpath syntax
  - array,object,sequence construction
  - object subscripting
  - lambda expressions
  - user-defined item methods and functions
- COPY with support of jsonpath

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Summary

- PostgreSQL is already good NoSQL database
  - Great roadmap
- SQL/JSON provides better flexibility and interoperability
  - JSON Path implementation (PG12) is the best !
- Jsonpath is superior for complex queries (thanks to internal executor)

Move from NoSQL to Postgres !

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References

- This talk: http://www.sai.msu.su/~megera/postgres/talks/jsonpath-pgday.it-2019.pdf
- Technical Report (SQL/JSON) - available for free
  http://standards.iso.org/i/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip
- Gentle introduction to JSON Path in PostgreSQL
  https://github.com/obartunov/sqljsondoc/blob/master/jsonpath.md
- Jsquery extension
  https://github.com/postgrespro/jsquery/tree/sqljson
- Play online with jsonpath
  http://sqlfiddle.postgrespro.ru/#!21/0/2379
- Jsonb roadmap - talk at PGConf.eu, 2018
  http://www.sai.msu.su/~megera/postgres/talks/sqljson-pgconf.eu-2017.pdf
- Parameters for opclasses
  http://www.sai.msu.su/~megera/postgres/talks/opclass_pgconf.ru-2018.pdf

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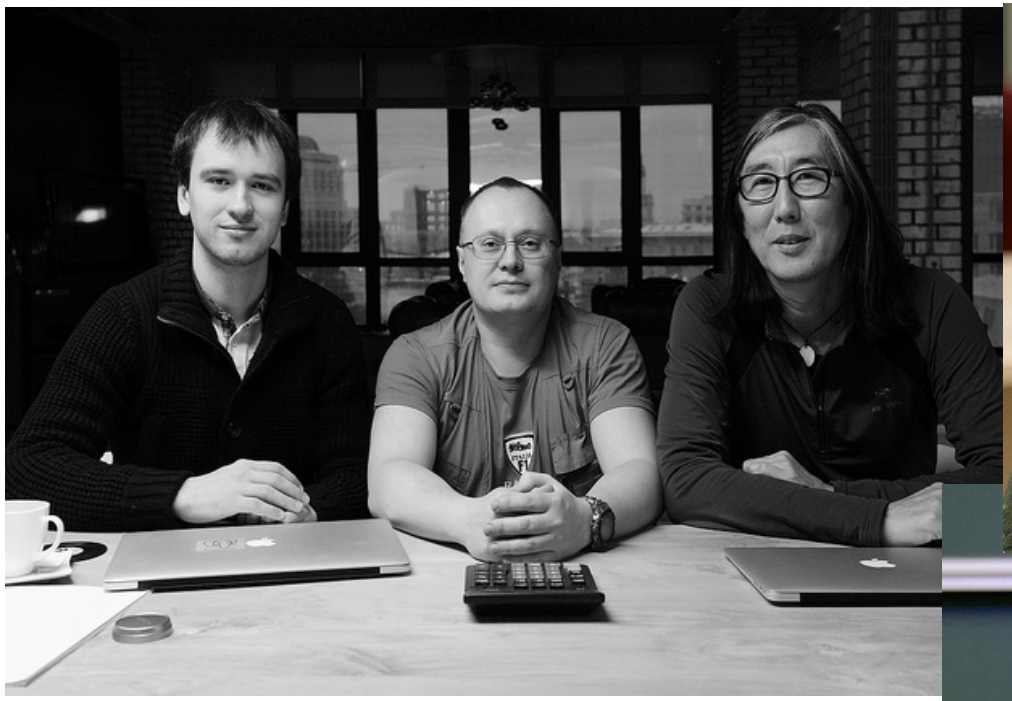
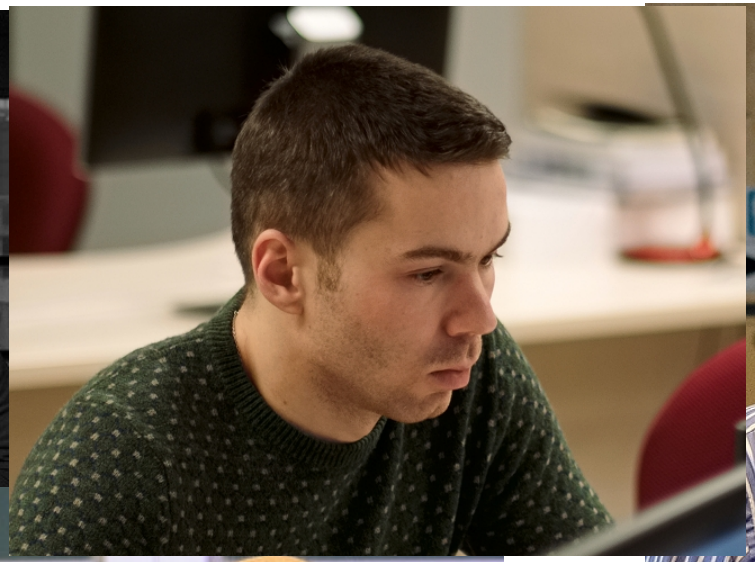
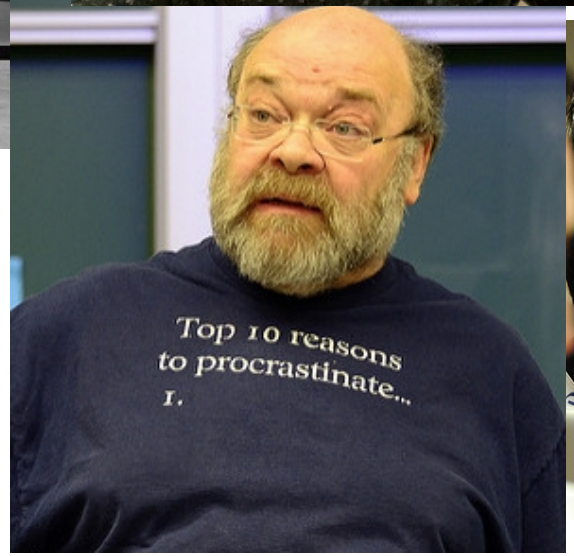
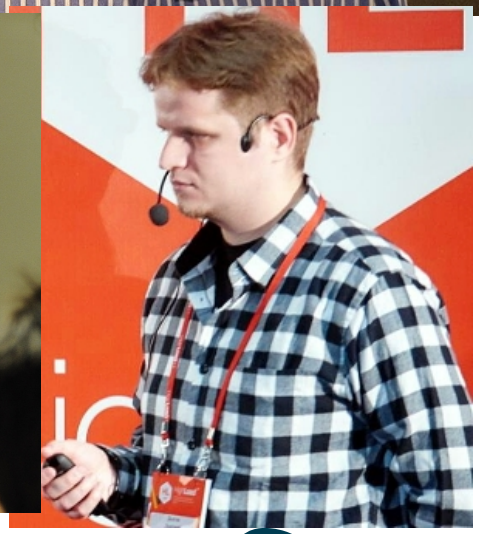
PEOPLE BEHIND NOSQL POSTGRES









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ADDENDUM I
SQL/JSON

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SQL/JSON in PostgreSQL

- The SQL/JSON **construction** functions (json[b]_xxx() functions):
  - JSON_OBJECT - construct a JSON[b] object.
    - json[b]_build_object()
  - JSON_ARRAY - construct a JSON[b] array.
    - json[b]_build_array()
  - JSON_ARRAYAGG - aggregates values as JSON[b] array.
    - json[b]_agg()
  - JSON_OBJECTAGG - aggregates name/value pairs as JSON[b] object.
    - json[b]_object_agg()

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SQL/JSON in PostgreSQL

- The SQL/JSON **retrieval** functions:
  - JSON_VALUE - Extract an SQL value of a predefined type from a JSON value.
  - JSON_QUERY - Extract a JSON text from a JSON text using an SQL/JSON path expression.
  - JSON_TABLE - Query a JSON text and present it as a relational table.
  - IS [NOT] JSON - test whether a string value is a JSON text.
  - JSON_EXISTS - test whether a JSON path expression returns any SQL/JSON items

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JSON_TABLE — relational view of json

- Table with rooms from json

```
SELECT  apt.*
FROM
  house,
  JSON_TABLE(js, '$.floor[0, 1]' COLUMNS (
    level int,
    NESTED PATH '$.apt[1 to last]' COLUMNS (
      no int,
      area int,
      rooms int
    )
  )) apt;
```

```
 level | no | area | num_rooms
-------+----+------+-----------
     1 |  1 |   40 |         1
     1 |  2 |   80 |         3
     1 |  3 |   50 |         2
     2 |  4 |  100 |         3
     2 |  5 |   60 |         2
(5 rows)
```

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ADDENDUM I
Parameters for Opclasses

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Parameters for opclasses

Operator class is a «glue» or named collection of:

- AM (access method)
- Set of operators
- AM specific support function

Examples:

- CREATE INDEX .. USING btree (textcolumn **text_pattern_ops**)
- CREATE INDEX .. USING gin (jsoncolumn **jsonb_ops**)
- CREATE INDEX .. USING gin (jsoncolumn **jsonb_path_ops**)

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Extending Indexing infrastructure

- Opclasses have «hardcoded» constants (signature size)
  - Let user to define these constants for specific data
- Indexing of non-atomic data (arrays, json[b], tsvector,…)
  - Specify what part of column to index — partial index only filters rows
- Use different algorithms to index
  - Specify what to use depending on data

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Parameters for opclasses: syntax

- Parenthized parameters added after column's opclass. Default opclass can be specified with DEFAULT keyword:

```
CREATE INDEX idx ON tab USING am (
    {expr {DEFAULT | opclass} ({name=value} [,…])} [,…]
) …
```

```
CREATE INDEX ON small_arrays USING gist (
      arr gist__intbig_ops(siglen=32),
      arr DEFAULT (num_ranges = 100)
);
CREATE INDEX bookmarks_selective_idx ON bookmarks USING
  gin(js jsonb_ops(projection='strict $.tags[*].term'));
```

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ADDENDUM I

Planner support for jsonpath

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Planner support function for jsonpath functions

- PG12+: API for planner support functions that lets them create derived index conditions for their functions.

```
CREATE [OR REPLACE] FUNCTION
  name ([[argmode] [argname] argtype [{DEFAULT|=} default_expr] [,…]])
{
  .........
  | SUPPORT support_function
  .........
} ...
```

- `jsonb_path_match()` transforms to *`jsonb @@ jsonpath`* (uses index !)

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Planner support function for jsonpath functions

- PG12+: API for planner support functions that lets them create derived index conditions for their functions.

```
SELECT * FROM t t1, t t2 WHERE
jsonb_path_match(t1.js, '$.a == $a', vars => t2.js, silent => true);
                                 QUERY PLAN
-------------------------------------------------------------------------------
 Nested Loop
   ->  Seq Scan on t t2
   ->  Bitmap Heap Scan n t t1
         Filter: jsonb_path_match(js, '($."a" == $"a")'::jsonpath,
t2.js, true)
         ->  Bitmap Index Scan on t_js_idx
               Index Cond: (js @@ jsonpath_embed_vars('($."a" ==
$"a")'::jsonpath, t2.js))
(6 rows)
```

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Planner support function for jsonpath functions

- PG12+: API for planner support functions that lets them create derived index conditions for their functions.

```
jsonb_path_match(b1.jb,
                 '$.title == $title && $.author != $author',
                 vars => b2.jb)
AND b2.jb ->> 'author' = 'ant.on'

=>

b1.jb @@ jsonpath_embed_vars('$.title == $title &&
                              $.author !=  $author', b2.jb)
AND b2.jb @@ '$.author == "ant.on"'::jsonpath
```

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ADDENDUM I

Jsonpath syntax extension

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Jsonpath syntax extensions

- Array construction syntax:

```
SELECT jsonb_path_query('[1,2,3]', '[0, $[*], 4]');
 [0, 1, 2, 3, 4]
```

- Object construction syntax:

```
SELECT jsonb_path_query('[1,2,3]','{a: $, "s": $.size()}');
 {"a": [1, 2, 3], "s": 3}
```

- Sequence construction syntax:

```
SELECT jsonb_path_query('[1,2,3]', '0, $[*], 4');
 0
 1
 2
 3
 4
```

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Jsonpath syntax extensions

- Object subscripting:

```
SELECT jsonb_path_query('{"a": 1}', '$["a"]');
 1


SELECT jsonb_path_query('{"a": 1, "b": "ccc"}', '$["a","b"])';
 1
 "ccc"


SELECT jsonb_path_query('{"a": 1}', 'lax $["a", "b"]');
 1

SELECT jsonb_path_query('{"a": 1}', 'strict $["a", "b"]');
 ERROR:  JSON object does not contain key "b"
```

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Jsonpath syntax extensions

- Array item methods with lambda expressions (ECMAScript 6 style):

```
SELECT jsonb_path_query('[1,2,3]', '$.map(x => x + 10)');
 [11, 12, 13]


SELECT jsonb_path_query('[1,2,3]', '$.reduce((x,y) => x + y)');
 6

SELECT jsonb_path_query('[1,2,3]', '$.fold((x,y) => x + y, 10)');
 16

SELECT jsonb_path_query('[1,2,3]', '$.max()');
 3
```

- Alternative syntax for lambdas: `'$.fold($1 + $2, 10)'`

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Jsonpath syntax extensions

- Sequence functions with lambda expressions:

```
SELECT jsonb_path_query('[1,2,3]', 'map($[*], x => x + 10)');
 11
 12
 13    -- sequence is returned, not array


SELECT jsonb_path_query('[1,2,3]', 'reduce($[*], (x,y) => x+y)');
 6

SELECT jsonb_path_query('[1,2,3]', 'fold($[*], (x,y)=>x+y, 10)');
 16

SELECT jsonb_path_query('[1,2,3]', 'max($[*])');
 3
```

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Jsonpath syntax extensions

- User-defined item methods and functions (`contrib/jsonpathx`):

```
CREATE FUNCTION map(jsonpath_fcxt) RETURNS int8
AS 'MODULE_PATHNAME', 'jsonpath_map' LANGUAGE C;

typedef struct JsonPathFuncContext
{
    JsonPathExecContext *cxt;
    JsonValueList *result;
    const char    *funcname;
    JsonItem      *jb;      /* @ */
    JsonItem      *item;    /* NULL => func, non-NULL => method */
    JsonPathItem  *args;
    void         **argscache;
    int           nargs;
} JsonPathFuncContext;
```

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ADDENDUM I
Performance of Intra joins

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Jsonpath intra joins (joining parts of the same column)

~ 5 000 ms

```
db.names.find({
  "roles.role": { $all: [ "actor", "editor" ] }, // find by index on "roles.role"
  $expr: {
    $setIntersection: [
      { $map: {                  // '$.roles[*] ? (@.role == "actor").title'
        input: {
          $filter: {             // '$.roles[*] ? (@.role == "actor")'
            input: "$roles",
            as: "r1",
            cond: { $eq: ["$$r1.role", "actor"] }
          }
        },
        as: "t1",
        in: "$$t1.title"
      }},
      { $map: {                  // '$.roles[*] ? (@.role == "editor").title'
        input: {
          $filter: {             // '$.roles[*] ? (@.role == "editor")'
            input: "$roles",
            as: "r2",
            cond: { $eq: ["$$r2.role", "editor"] }
          }
        },
        as: "t2",
        in: "$$t2.title"
      }}
    ]
  }
}).explain("executionStats").executionStats.executionTimeMillis
```

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Jsonpath intra joins (joining parts of the same column)

- Query: find all the actors who were editors in **the same movie** (6378007 rows in names).
- Relational analogue of names table:

```
CREATE TABLE roles AS
SELECT
  id,
  r->>'role' AS "role",
  r->>'title' AS "title",
  r->>'character' AS "character",
  r->'ranks' AS "ranks"
FROM
  names,
  jsonb_array_elements(jb->'roles') roles(r);


CREATE INDEX ON roles(role);
CREATE INDEX ON roles (id, title, role); -- composite btree index

\d+

 public | names                    | table | 3750 MB
 public | roles                    | table | 5830 MB

\di+

 public | names_jb_idx             | index | names | 1439 MB
 public | roles_id_title_role_idx | index | roles | 4710 MB
```

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Jsonpath intra joins (joining parts of the same column)

- Query: find all the actors who were editors in **the same movie** (6378007 rows in names).
- Relational analogue of names table:
- ```
  SELECT DISTINCT r1.id
  FROM roles r1
  WHERE r1.role ='editor' AND EXISTS (
    SELECT FROM roles r2 WHERE r2.id = r1.id AND r2.title = r1.title AND r2.role = 'actor'
  );
  ```

```
Sequential Scan:                34840.434 ms
Sequential Scan (parallel,6):    4233.829 ms
Bitmap Index Scan:              34454.714 ms
Bitmap Index Scan(parallel,6):   3807.380 ms
```

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```