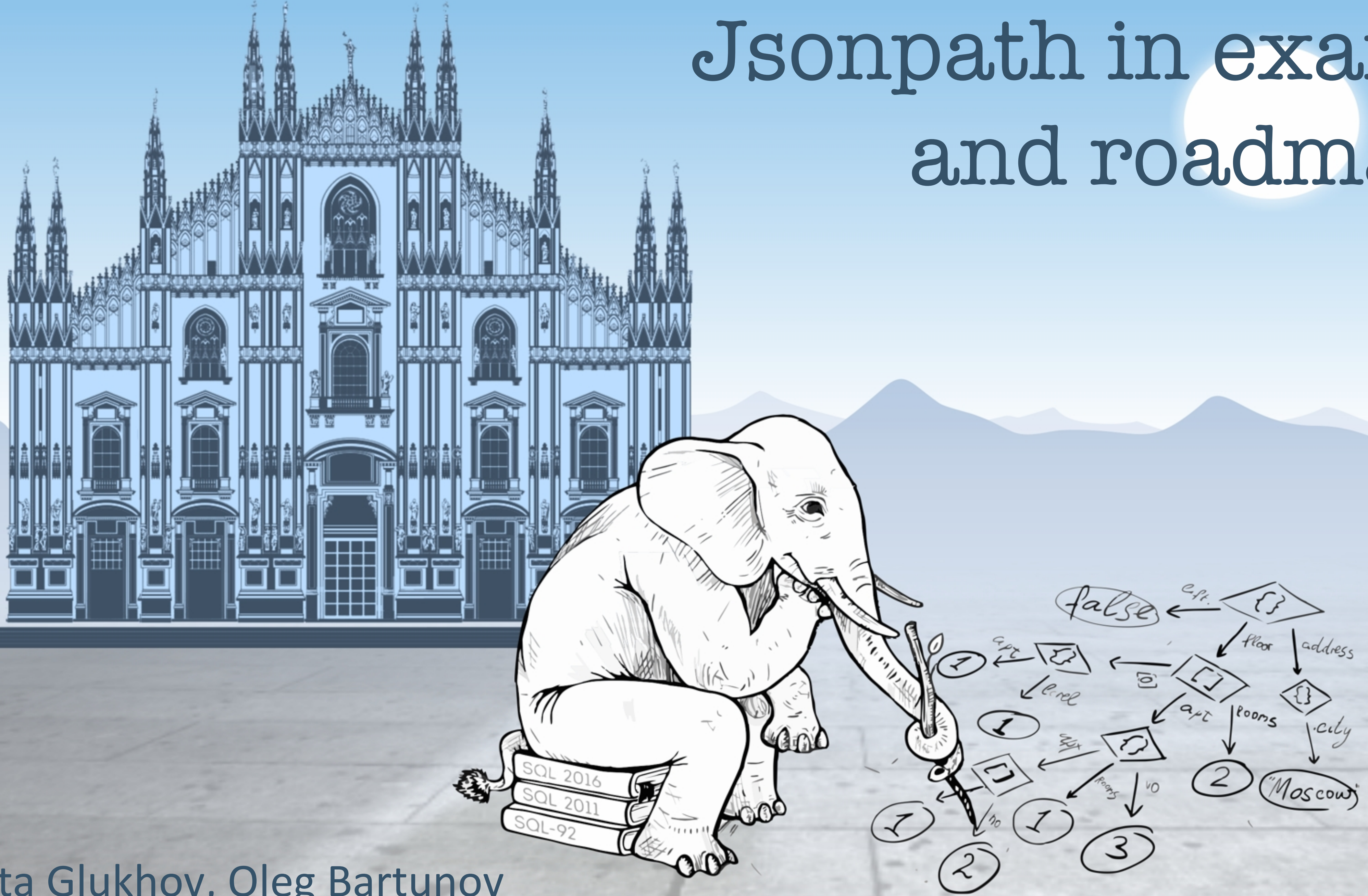
Jsonpath in examples and roadmap



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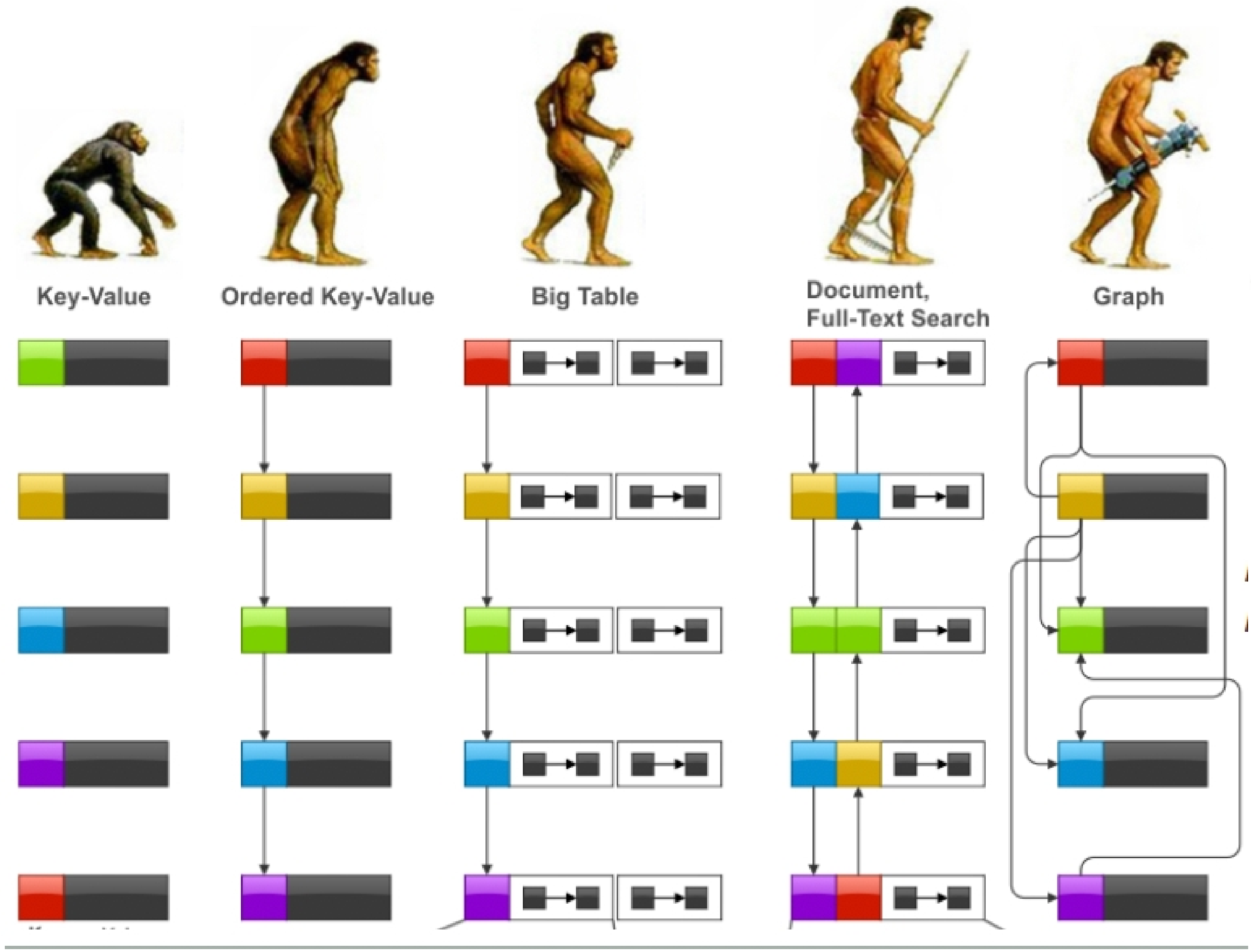
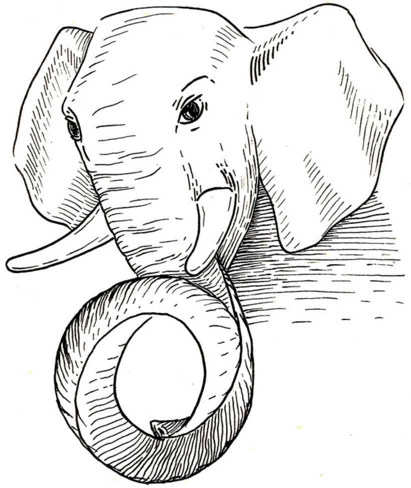
NOSQL POSTGRES IN SHORT





SQL/JSON — 2020
- Complete SQL/JSON
- Better indexing, syntax

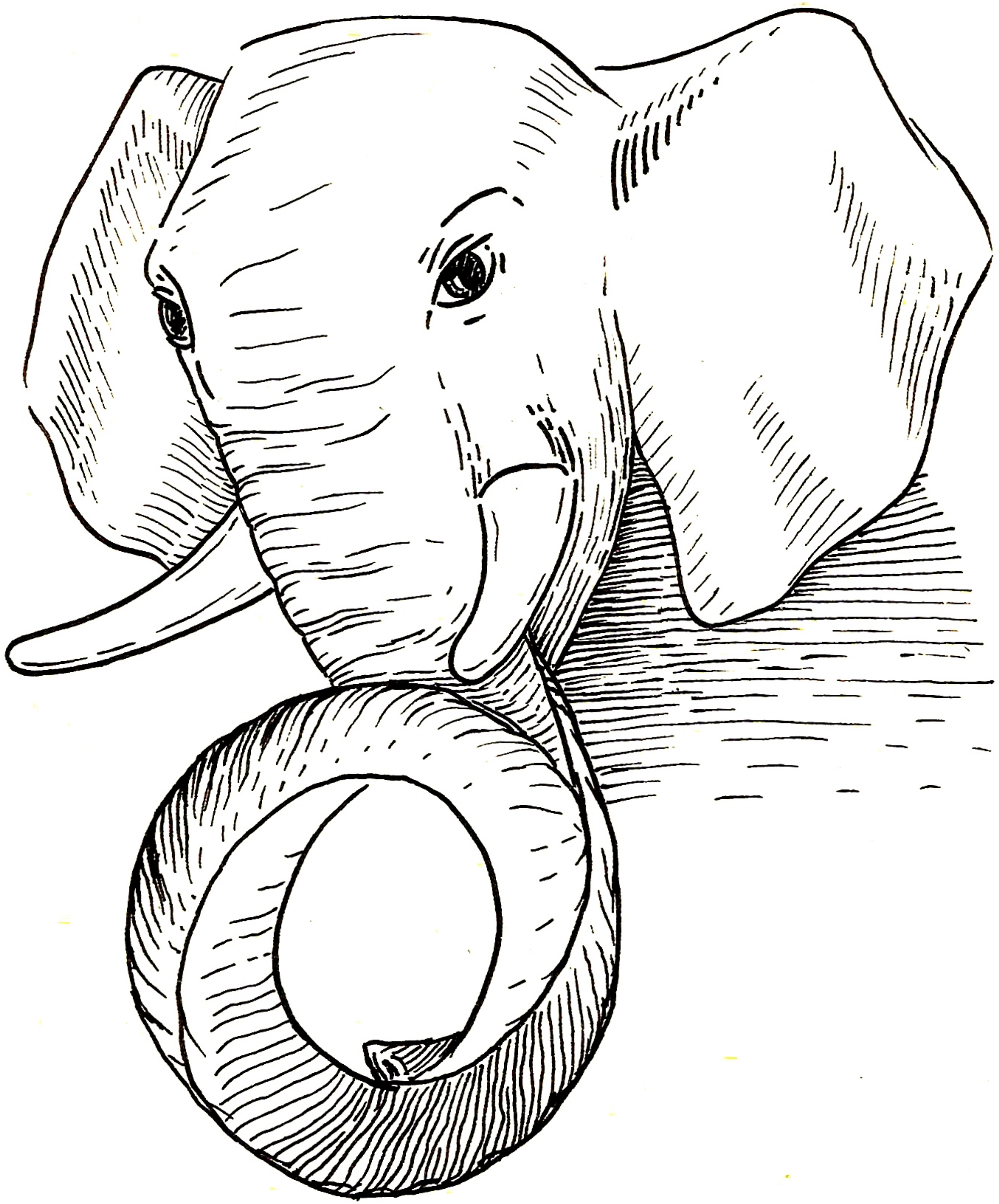
JSONPATH - 2019
- SQL/JSON — 2016
- Functions & operators
- Indexing

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

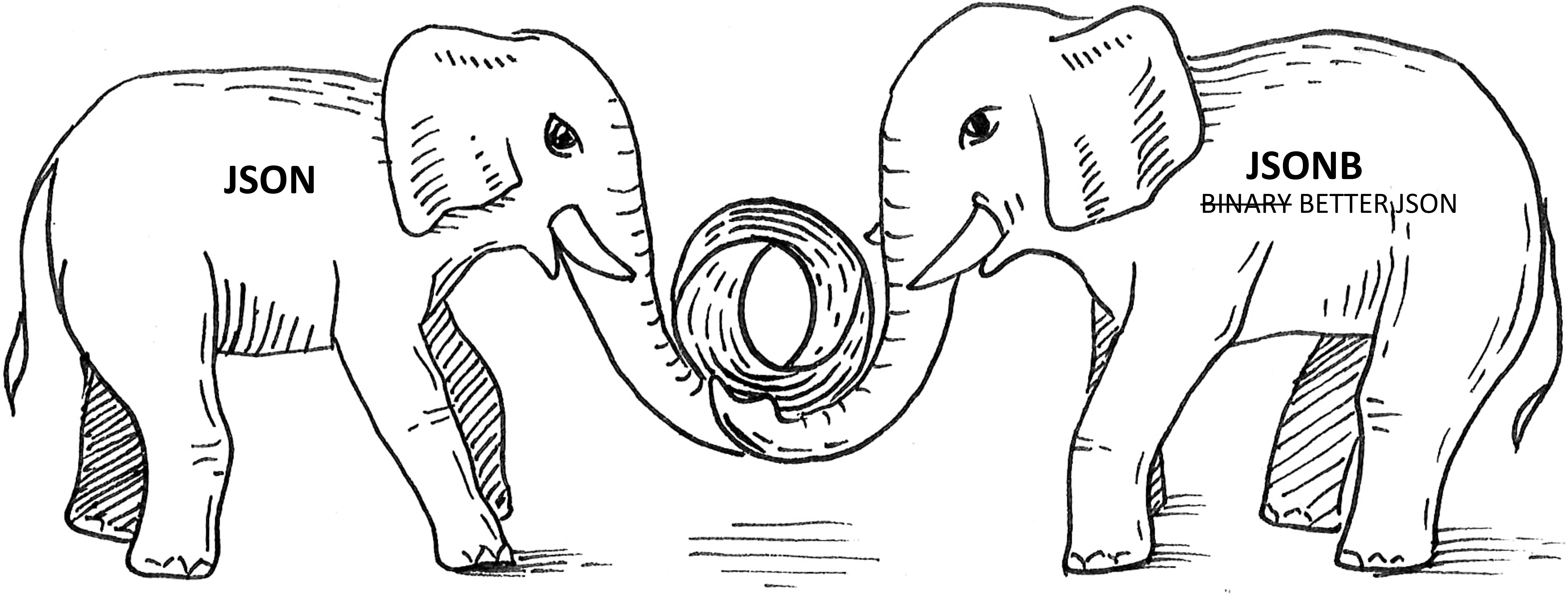
PostgresPro



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}
```

- 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*), "arrow" operators
- jsonb: great performance, thanks to indexes
- JsQuery ext. - json query language with GIN indexing support

JSONB is GREAT, BUT ...

JSON[B] is a black box for SQL

```
WITH RECURSIVE t(id, value) AS ( SELECT * FROM
js_test
 UNION ALL
    (
      SELECT
        t.id,
        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
  js_test.*
FROM
  (SELECT id FROM t WHERE value @> '{"color":
"red"}' GROUP BY id) x
  JOIN js_test ON js_test.id = x.id;
```

SELECT * FROM js_test;

```
 id |                          value
----+---------------------------------------------------------------------
  1 | [1, "a", true, {"b": "c", "f": false}]
  2 | {"a": "blue", "t": [{"color": "red", "width": 100}]}
  3 | [{"color": "red", "width": 100}]
  4 | {"color": "red", "width": 100}
  5 | {"a": "blue", "t": [{"color": "red", "width": 100}], "color": "red"}
  6 | {"a": "blue", "t": [{"color": "blue", "width": 100}],"color": "red"}
  7 | {"a": "blue", "t": [{"color": "blue", "width": 100}],"color": "red"}
  8 | {"a": "blue", "t": [{"color": "green", "width": 100}]}
  9 | {"color": "green", "value": "red", "width": 100}
(9 rows)
```

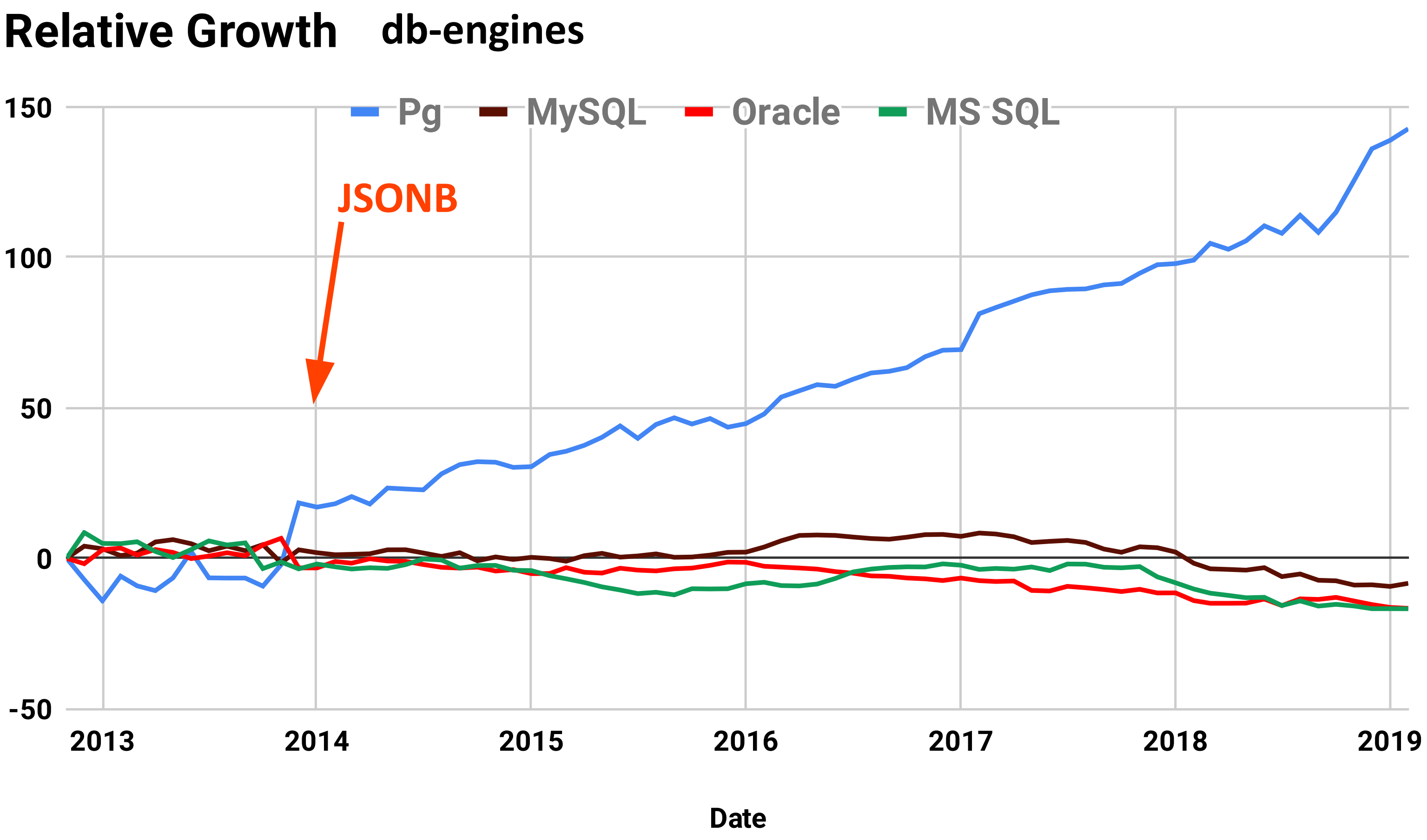
Jsquery (2014)

https://github.com/postgrespro/jsquery/

```
SELECT * FROM js_test
WHERE
value @@  '*.color = "red"';
```

Postgres revolution: embracing relational databases

- NoSQL users attracted by the NoSQL Postgres features



18 декабря 2014

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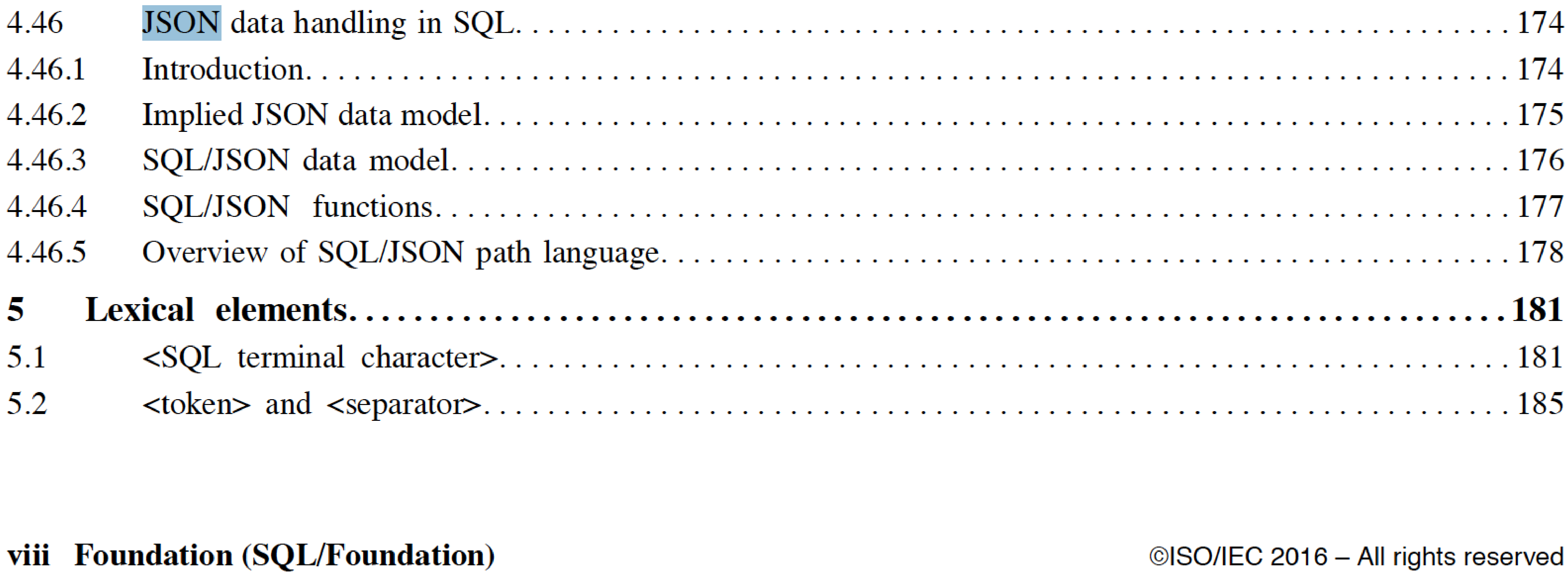
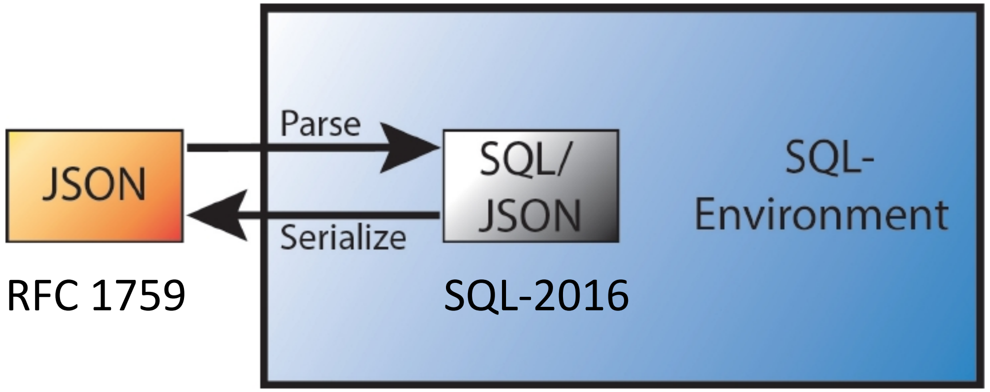
JSONB and JsQuery are GREAT, BUT ...
OH, REALLY ?
SQL Standard now loves JSON !

SQL/Foundation recognized JSON after 8 years



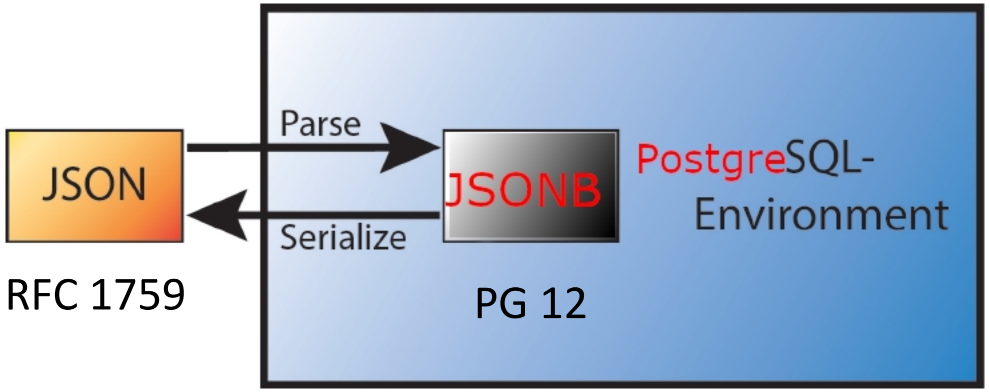
viii Foundation (SQL/Foundation)

SQL/JSON in SQL-2016



- SQL/JSON data model
  - *A sequence of SQL/JSON items*, each item can be (recursively) any of:
    - SQL/JSON scalar — non-null value of SQL types: Unicode character string, numeric, Boolean or datetime
    - SQL/JSON *null,* value that is distinct from any value of any SQL type (not the same as NULL)
    - SQL/JSON arrays, ordered list of zero or more SQL/JSON items — SQL/JSON *elements*
    - SQL/JSON objects — unordered collections of zero or more SQL/JSON *members* (key, SQL/JSON item)
- JSON Path language
  - Describes a <projection> of JSON data to be used by SQL/JSON functions
- SQL/JSON functions (9)
  - Construction functions: values of SQL types to JSON values
  - Query functions: JSON values to SQL types
    JSON Path(JSON values) → SQL/JSON types -> converted to SQL types

SQL/JSON in PostgreSQL



- SQL/JSON data model
  - **Jsonb is the (practical) subset of SQL/JSON data model ORDERED and UNIQUE KEYS**
- JSON Path language
  - Describes a <projection> of JSON data (to be used by SQL/JSON functions)
  - **Most important part of SQL/JSON - committed to PG12 !**
- SQL/JSON functions
  - Constructor functions: **json[b] construction functions**
  - Query functions: **need some functions/operators with jsonpath support**
- Indexes
  - **Use already existing indexes (built-in, jsquery)**
    Add support of jsonpath to the existing opclasses

JSON Path query language

- **JSON Path** expression specify the parts of json. It 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)

```
 'lax $.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
  - Item methods - '$.a.b.c.x.type()'

    type(), size(), double(), ceiling(), floor(), abs(), keyvalue(), datetime()

JSON Path examples 1/3

- 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

JSON Path examples 2/3

- 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
```

JSON Path examples 3/3

- 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 ".ceiling()"

jsonb '1.2' | '(($ + 1).abs() * 2).ceiling()' | 5

Syntactical errors in 'jsonpath' are reported:
SELECT '$a. >1'::jsonpath;
ERROR:  syntax error, unexpected GREATER_P at or near ">" of jsonpath input
```

JSON Path filter

- A filter 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: ? (JSON path predicate) — filter can be nested, since predicate itself could contains JSON path with filter
- Predicate: True, False, Unknown (any errors in operands — structural, arithmetic, incomparable items)

JSON Path filter

- A filter 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.
- Filter works as follows:
  1) In lax mode, any SQL/JSON arrays in the operand are unwrapped
  2)The predicate is evaluated fo each SQL/JSON item in the SQL/JSON sequence
  3)The result is those SQL/JSON items for which the predicate resulted in <u>True</u>.
- The special variable @ in filter is a reference the current SQL/JSON item in the SQL/JSON sequence. The value of @ is the current SQL/JSON item of the first operand of the innermost filter with @.

JSON Path filter

- Predicates:
  - Comparison predicates ==, !=, <>, <, <=, >, and >=
    Compares all pairs from left and right operands
  - Logical predicates &&, ||, !
  - *exists*, test if a path expression has a non-empty result
    '$[*] ? (exists (@[*] ? (@> 2)))'
  - *like_regex* for string pattern matching.
    Optional *flag* can be combination of i, s (default), m, x.
    '$[*] ? (@ like_regex "as" flag "i")
  - *starts with* to test for an initial substring (prefix)
    '$[*] ? (@ starts with "as")'
  - *is unknown* to test for *Unknown* results. Its operand should be in parentheses.
    '$[*] ? ((@ == 5) is unknown)'

JSON Path filters

- Errors in operands of predicates converted to *unknown* independent on lax/strict mode.

```
jsonb '[1,"a",2]'

'$[*] ? (1/@ > 0)'                    | 1,2
'$[*] ? ((1/@ > 0) is unknown)' | "a" (source of error)
```

JSON Path methods

- Predefined methods transforms each item to sequence

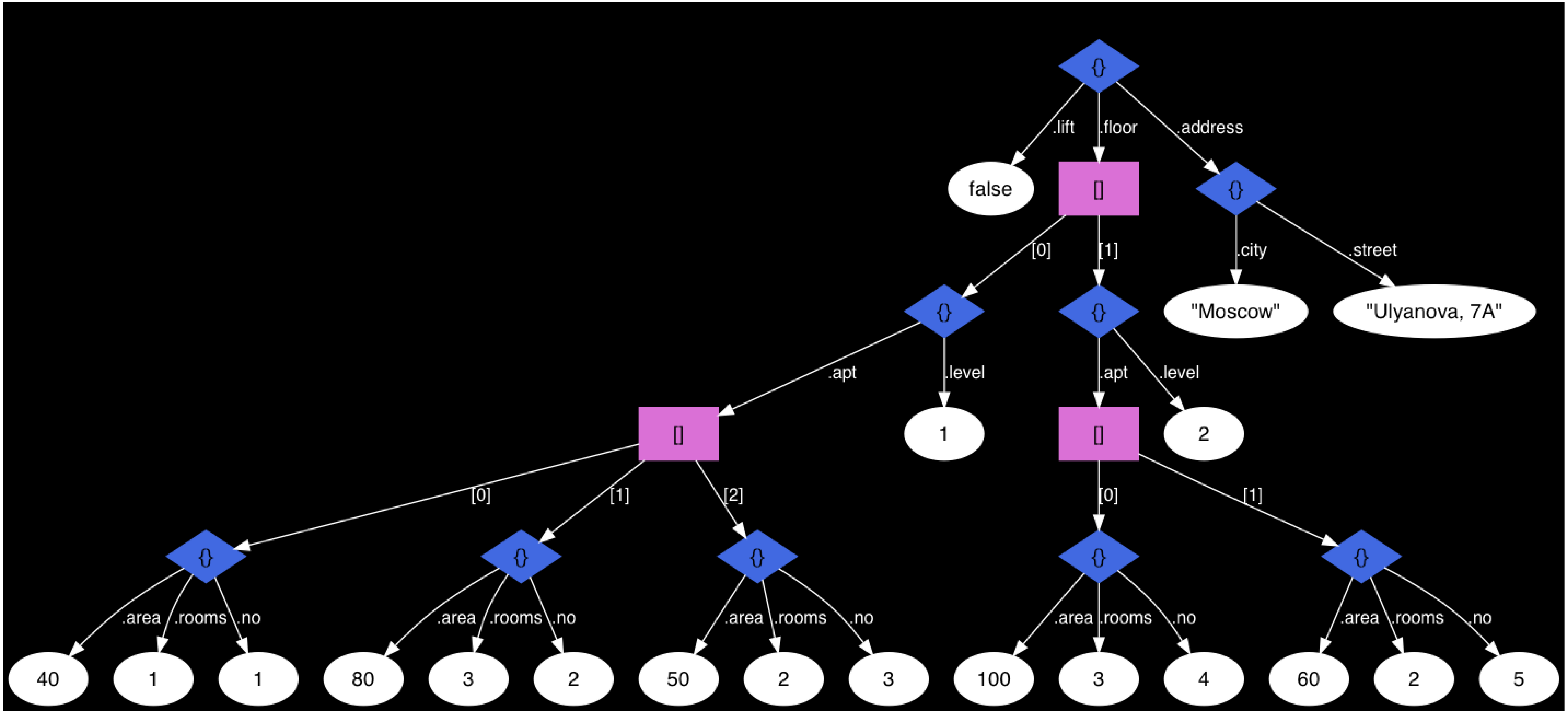
```
jsonb '[{"a":5, "b":2},{"c": 3, "d": 4},{}]'

'$[*]'               | {"a": 5, "b": 2}, {"c": 3, "d": 4},{}
'$[*].keyvalue()' | {"id": 16, "key": "a", "value": 5},
                     {"id": 16, "key": "b", "value": 2},
                     {"id": 56, "key": "c", "value": 3},
                     {"id": 56, "key": "d", "value": 4}
```

- There are could be several methods

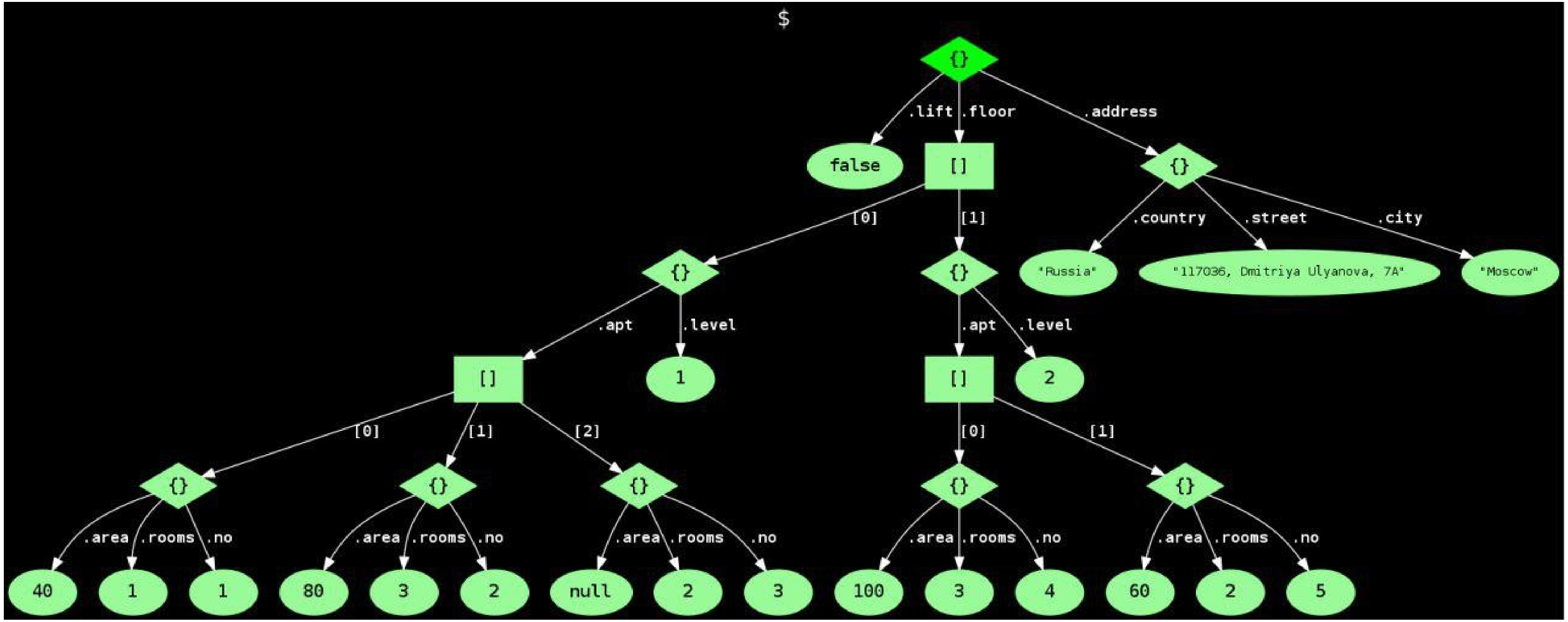
```
jsonb '1.2' | '(($ + 1).abs() * 2).ceiling()' | 5
```

Two floors house



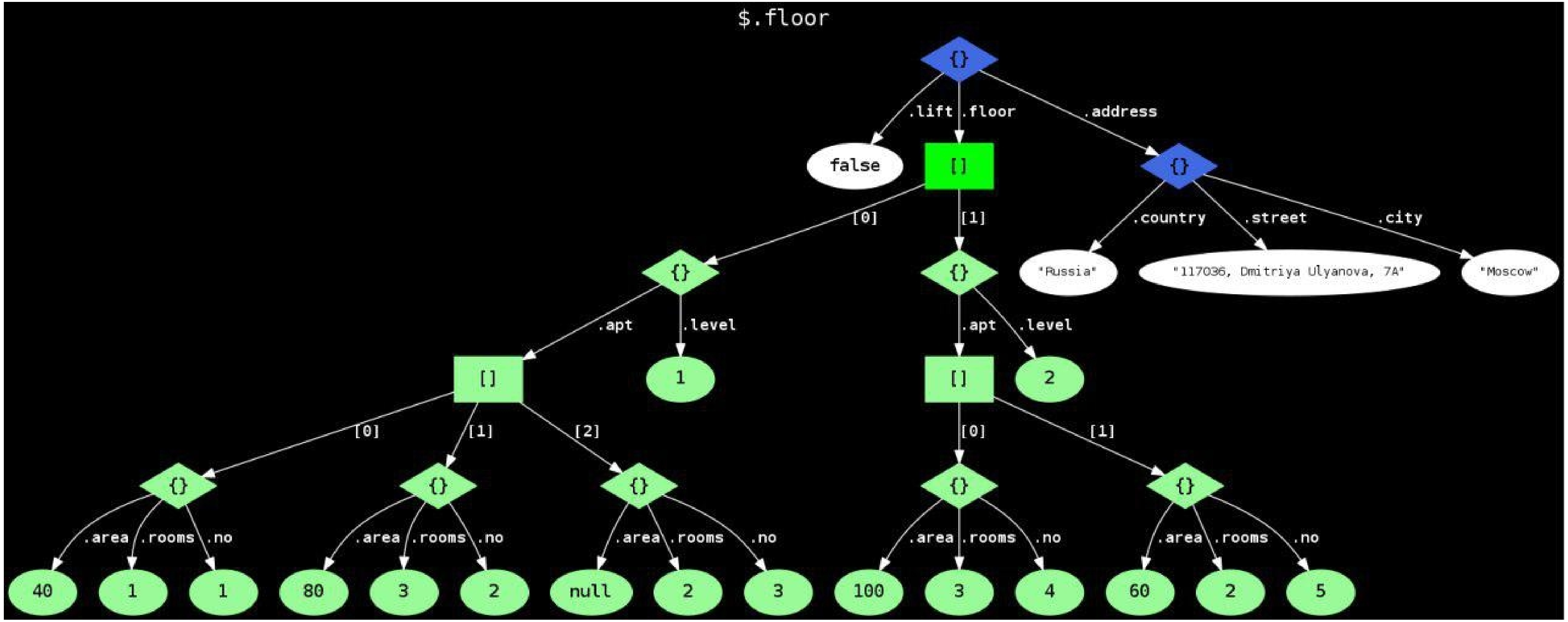
How path expression works (1)

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



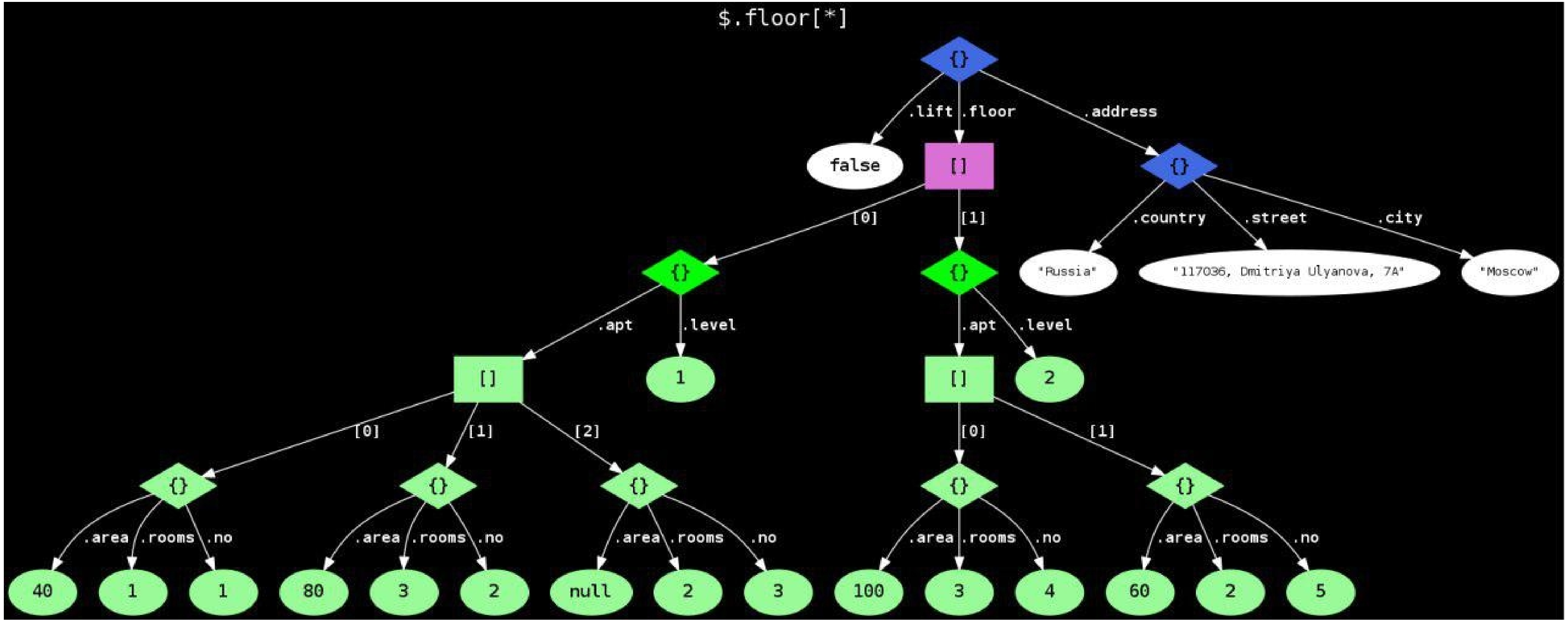
How path expression works (2)

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



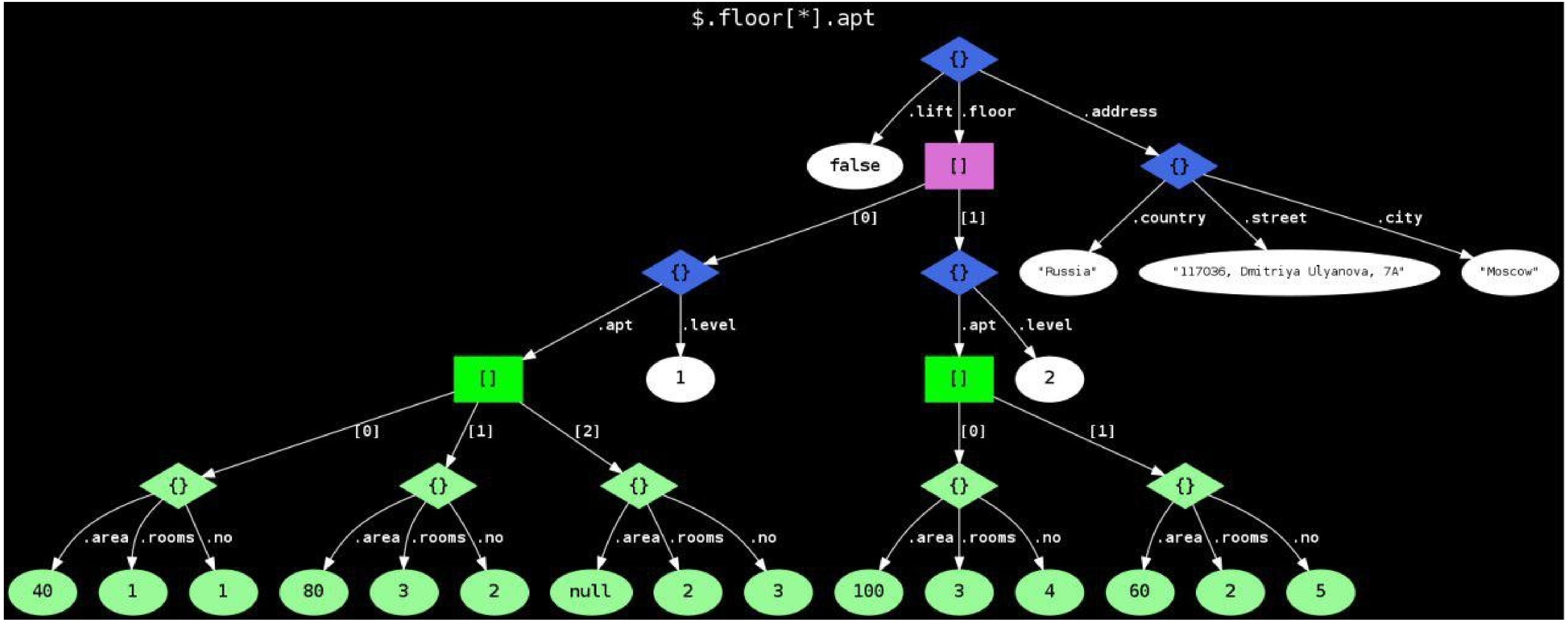
How path expression works (3)

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



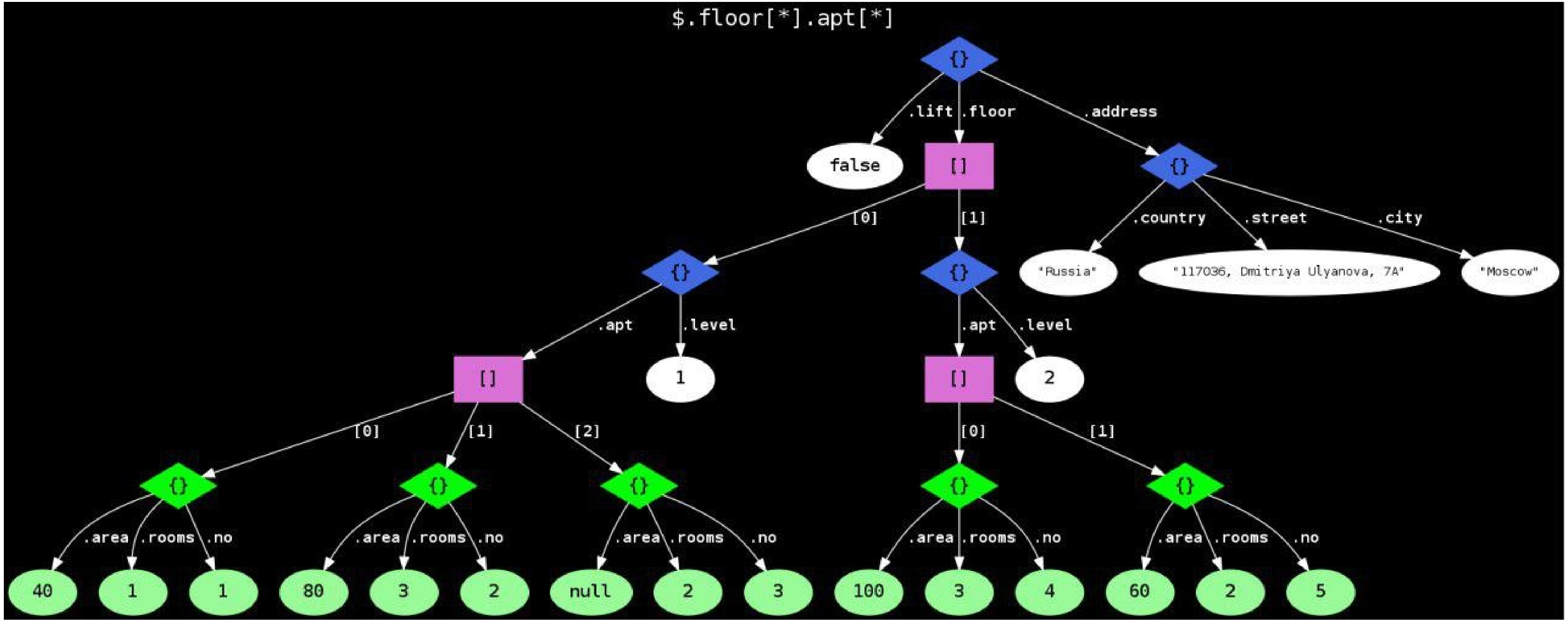
How path expression works (4)

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



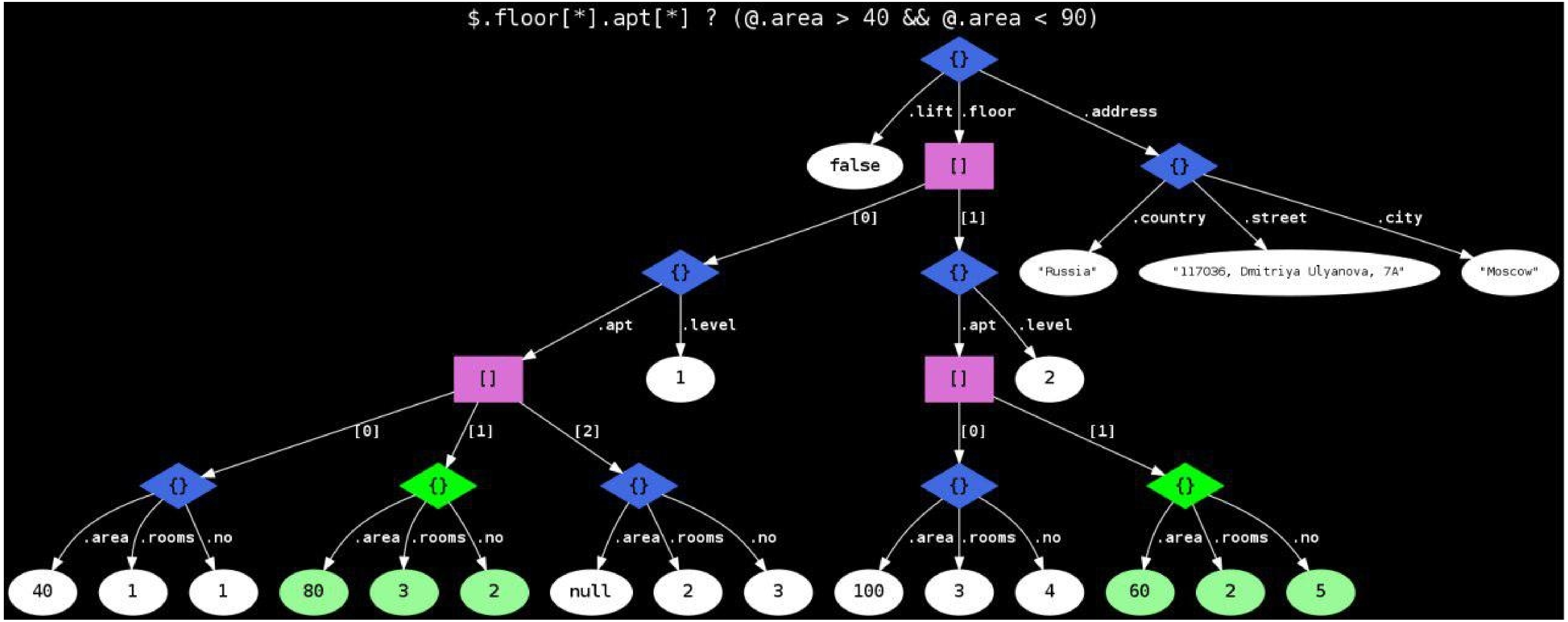
How path expression works (5)

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



How path expression works (6)

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



How path expression works (summary)

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

1) $ - SQL/JSON seq. of length 1, json itself
2) .floor — SQL/JSON seq. of length 1, an array floor
3) [*] – SQL/JSON seq. of length 2, an array of two objects (2 floors)
4) .apt — SQL/JSON seq. of length 2, two arrays of objects (appartments on each floor)
5) [*] - SQL/JSON seq. of length 5, extracts five objects (appartments)
6) Each appartment filtered by (@.area > 40 && @.area < 90) expression

The result is a sequence of two SQL/JSON items

JSON Path: [lax] vs strict

lax and *strict* modes used to facilitate matching of the (sloppy) document structure and path expression

- Handling of structural error — Errors ignored in lax mode, error status returned
  - Missing object key

```
  jsonb '[{"a":1},{"b":2},{"a":3}]'

'lax $[*].* ? (@ > 0)'   | 1,2,3
'lax $[*].a ? (@ > 0)'   | 1,3
'strict $[*].a ? (@ > 0)'| ERROR: object does not contain key "a"
```

JSON Path: [lax] vs strict

lax and *strict* modes used to facilitate matching of the (sloppy) document structure and path expression

- Handling of structural error — Errors ignored in lax mode, error status returned

- Access to SQL/JSON item of wrong type
  jsonb '[{"a":1},2,{"a":3}]'

```
'lax $[*].* ? (@ > 0)'   | 1,3
'lax $[*].a ? (@ > 0)'   | 1,3
'strict $[*].a ? (@ > 0)'| ERROR: jsonpath member accessor can only
                         |        be applied to an object
```

JSON Path: [lax] vs strict

`*lax* and *strict* modes used to facilitate matching of the (sloppy) document structure and path expression`

- Handling of structural error — Errors ignored in lax mode, error status returned
  - Predicate returns *unknown* if operands report error status

```
jsonb '[{"a":1},{"b":2},{"a":3},4]'

'lax $[*] ? (@.a > 0)'                  | {"a":1},{"a":3}
'strict $[*] ? (@.a > 0)'               | {"a":1},{"a":3}
'lax $[*] ? ((@.a > 0) is unknown)'     |
'strict $[*] ? ((@.a > 0) is unknown)'  | {"b":2},4
```

JSON Path: [lax] vs strict

- Lax: arrays are unwrapped
  Strict: requires an exact nesting
  jsonb '[1,2,[3,4,5]]'

```
'lax $[*] ? (@ == 5)'        | 5
'lax $    ? (@ == 5)'        | [3,4,5]
'strict $[*] ? (@[*] == 5)' | [3,4,5]
'strict $[*] ? (@ == 5)'     |
'strict $[*] ? ((@ == 5) is unknown)' | [3,4,5]
```

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 implemented boolean operators (exists, match) 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,...)

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.

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]
```

Jsonpath functions

- "silent" flag enables suppression of errors:

```
SELECT jsonb_path_query('[]', 'strict $.a');
ERROR:  jsonpath member accessor can only be applied to an object

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

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)
  ```

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
  ```

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
  ```

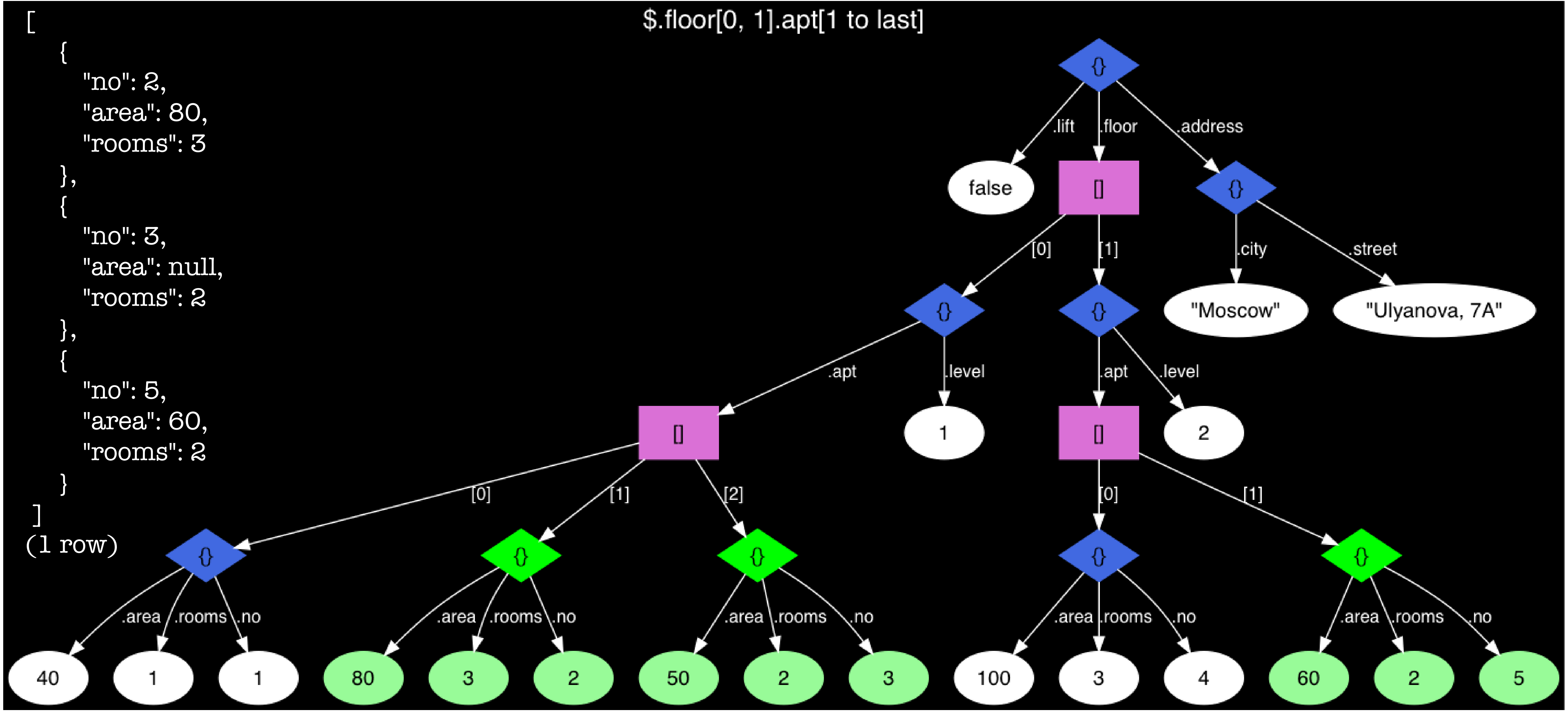
- `jsonb @@ jsonpath` (match)
  Evaluate JSON path predicate (*unknown* converts to SQL NULL)

  ```
  jsonb '[1,2,3]' @@ '$[*] == 3'   => true
  jsonb '1' @@  '$/0 > 1'          => NULL
  ```

- These operators are interchangeable:

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

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



```
[
    {
        "no": 2,
        "area": 80,
        "rooms": 3
    },
    {
        "no": 3,
        "area": null,
        "rooms": 2
    },
    {
        "no": 5,
        "area": 60,
        "rooms": 2
    }
]
(1 row)
```

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

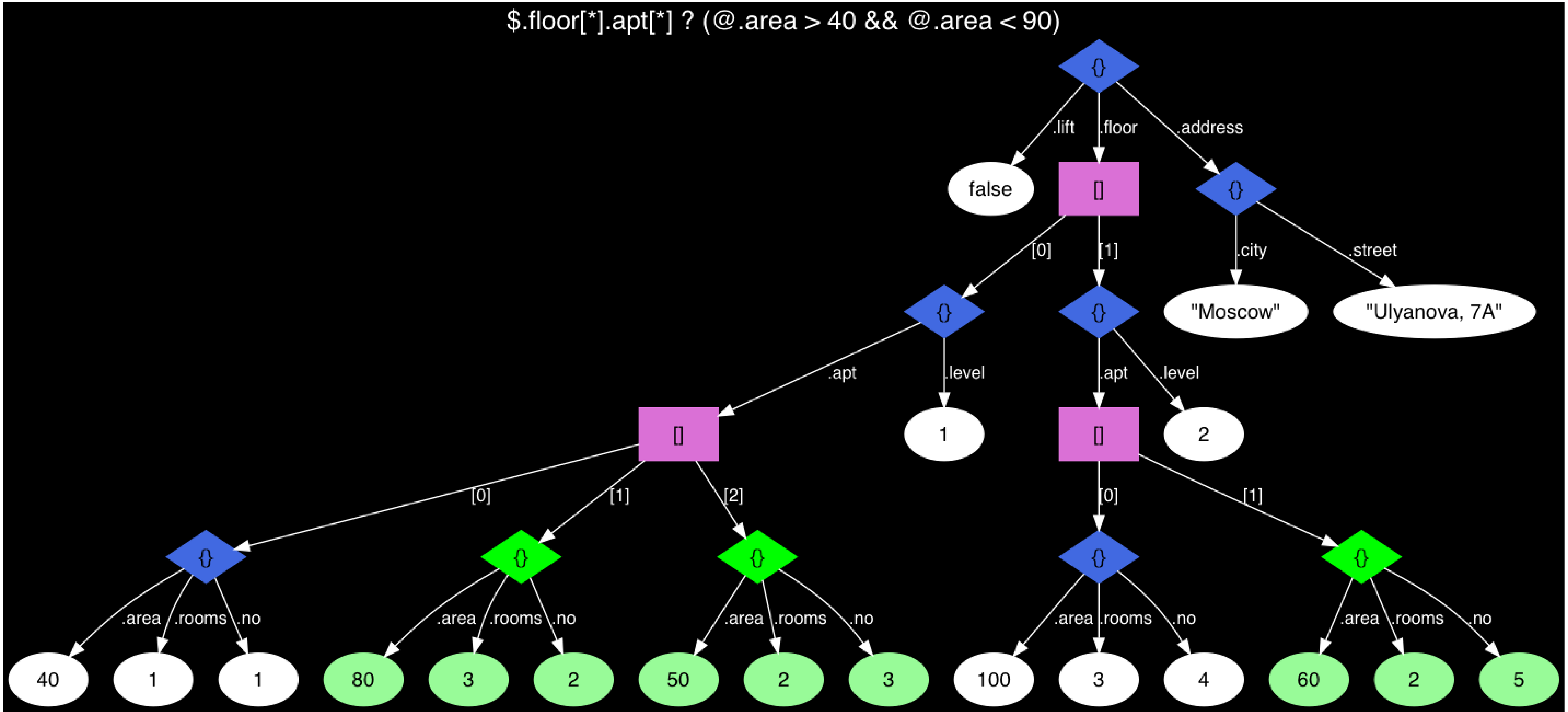
- PG12 (jsonpath) query

```
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);
```

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



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

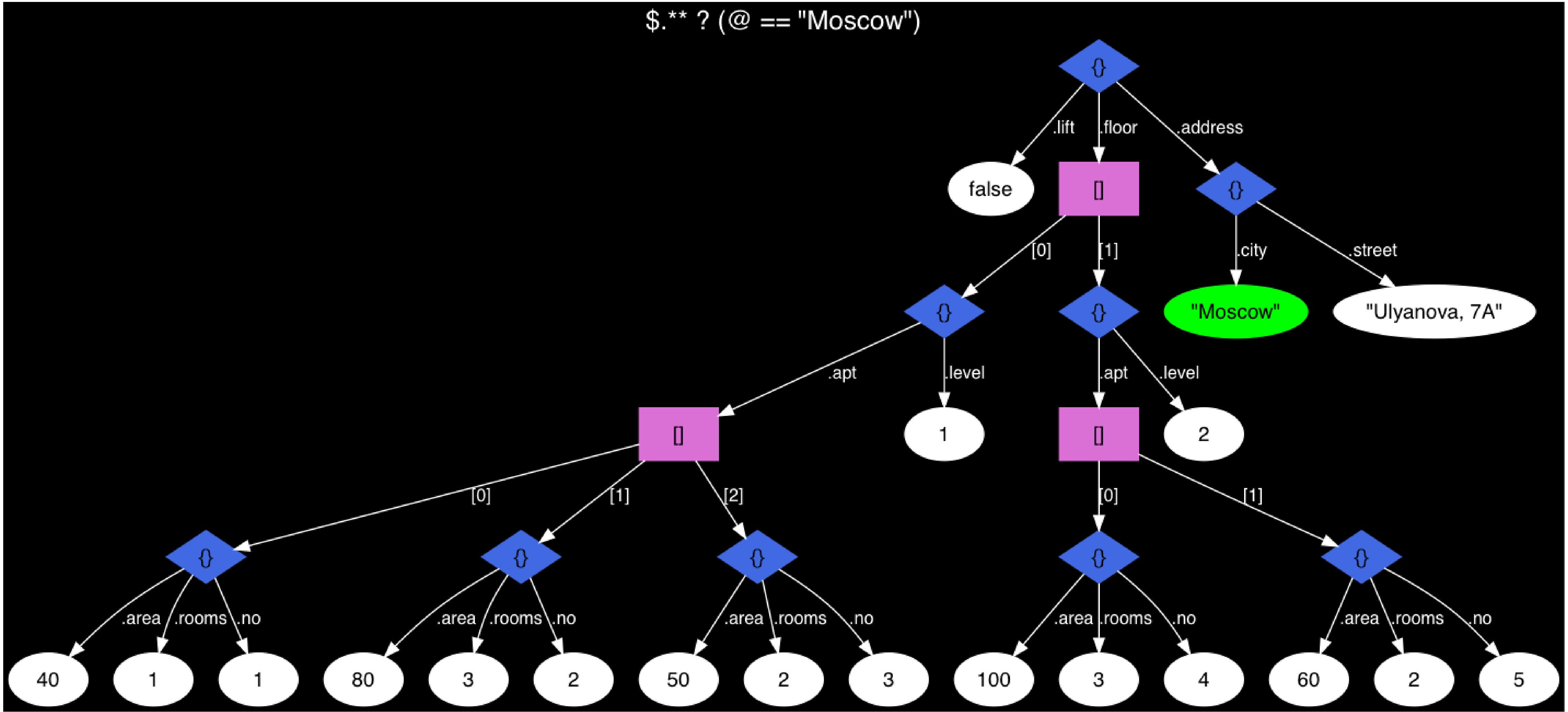
- PG12 (jsonpath) query

```
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;
```

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



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.
```

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"');
```

JSON Path in PG12: one missing feature

- `.datetime()` item method (T832) not supported in PG12:

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


-- behavior required by standard (PG13)
SELECT jsonb_path_query('"13.03.2019"',
'$.datetime("DD.MM.YYYY")');
 jsonb_path_query
------------------
 "2019-03-13"
(1 row)
```

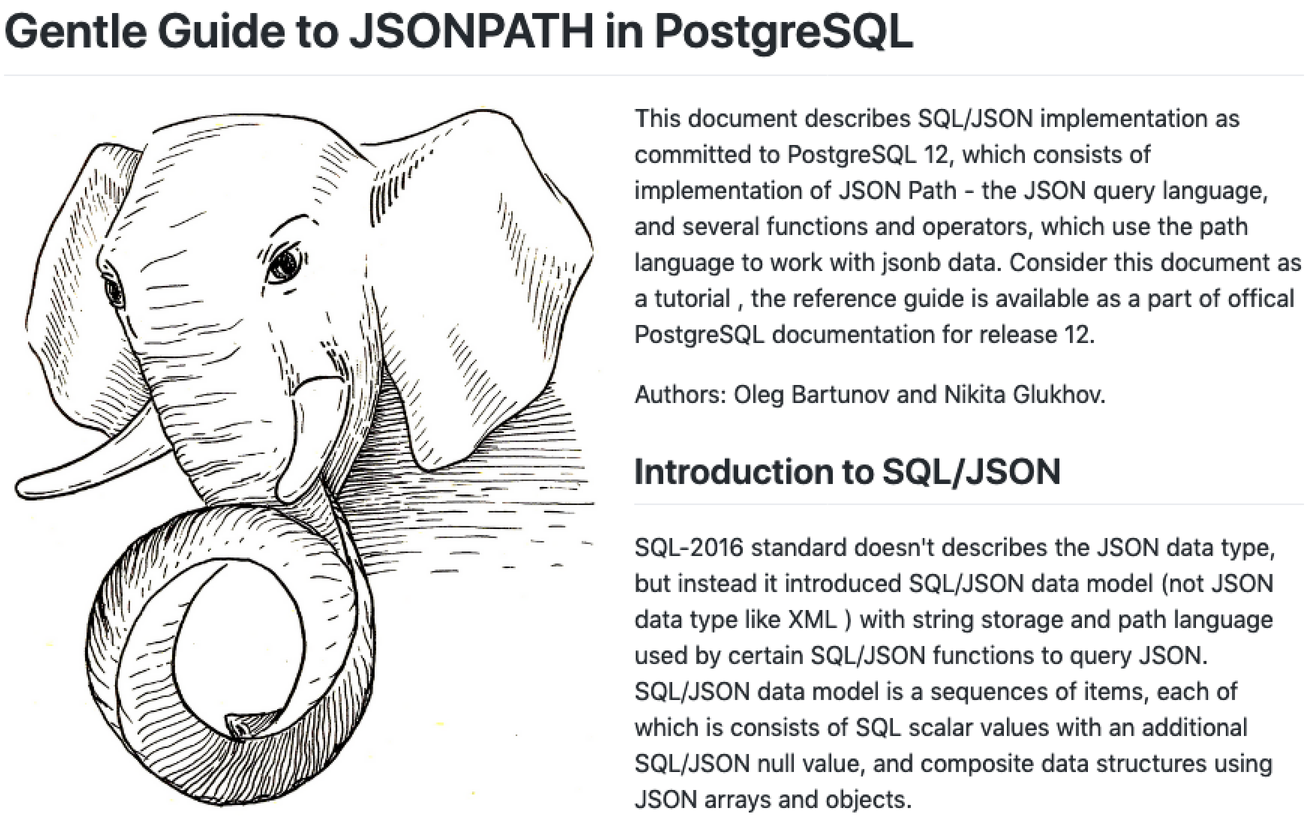
SQL/JSON standard conformance

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

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.

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 @>)

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.

Jsonpath queries could use existing jsonb indexes

- 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

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))) AS js
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)
```

Jsonpath performance (simple queries)

- Performance of arrow operators is slightly better for simple queries, but jsonpath allows more complex queries.

```
                            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 == $x',                     | 1100      |immutable
                   jsonb_object(array['x'], array['123'])) |           |
 jsonb_path_match(js, '$.x.y.z == $x',                     | 2800      | stable
                   jsonb_build_object('x', '123'))         |           |
 jsonb_extract_path(js, 'x', 'y', 'z') = '"123"'           | 1670      |
 jsonb_extract_path_text(js, 'x', 'y', 'z') = '123'        |  580      |
```

Jsonpath performance (complex queries)

- Test table with 1 mln rows

```
CREATE TABLE t AS
SELECT jsonb_agg(i)::jsonb js
FROM generate_series(0, 9999999) i GROUP BY i / 10;

SELECT * FROM tt LIMIT 10;
                                             js
--------------------------------------------------------------------------------------------
 [7900, 7901, 7902, 7903, 7904, 7905, 7906, 7907, 7908, 7909]
 [6627180, 6627181, 6627182, 6627183, 6627184, 6627185, 6627186, 6627187, 6627188, 6627189]
 [6943390, 6943391, 6943392, 6943393, 6943394, 6943395, 6943396, 6943397, 6943398, 6943399]
 [2333380, 2333381, 2333382, 2333383, 2333384, 2333385, 2333386, 2333387, 2333388, 2333389]
 [1299760, 1299761, 1299762, 1299763, 1299764, 1299765, 1299766, 1299767, 1299768, 1299769]
 [7560020, 7560021, 7560022, 7560023, 7560024, 7560025, 7560026, 7560027, 7560028, 7560029]
 [1641250, 1641251, 1641252, 1641253, 1641254, 1641255, 1641256, 1641257, 1641258, 1641259]
 [5020840, 5020841, 5020842, 5020843, 5020844, 5020845, 5020846, 5020847, 5020848, 5020849]
 [1575140, 1575141, 1575142, 1575143, 1575144, 1575145, 1575146, 1575147, 1575148, 1575149]
 [5035140, 5035141, 5035142, 5035143, 5035144, 5035145, 5035146, 5035147, 5035148, 5035149]
(10 rows)
```

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Jsonpath performance (complex queries)

- Performance of jsonpath for complex queries is better, because of internal executor.

```
                             query                               | time, ms
----------------------------------------------------------------------
js @> '1'                                                        | 620
js @@ '$[*] == 1'                                                | 1274
exists (select from jsonb_array_elements(js) e where e = '1')    | 5926

js @@ '$[*] < 1'                                                 | 1268
exists (select from jsonb_array_elements(js) e where e < '1')    | 5927

js @@ '$[0 to 9] < 1'                                            | 2133
exists (select from generate_series(0,9) i where js->i < '1')    | 6263

js @@ '$[2 to 4] < 1'                                            | 1338
exists (select from generate_series(2,4) i where js->i < '1')    | 2134
```

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
&&
            $.roles[*].role == "editor" &&
            $.roles[*].role == "actor"
';
```

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

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

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.

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

- **Jsonpath**:

```
SELECT jb->'id' FROM names
WHERE jb @@ '$.roles[*] ? (@.role == "actor").title ==
             $.roles[*] ? (@.role == "editor").title';
  Sequential Scan:                  29748.223 ms
  Sequential Scan (parallel):        4678.925 ms
  Bitmap Index Scan (jsquery index):  2328.880 ms
```

- **«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
```

Jsonpath intra joins (joining parts of the same column)

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

- Jsonpath:

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

- 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:                 13745.517 ms
Bitmap Index Scan(parallel,6):      3807.380 ms
```

- Mongo: 3808 ms

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

Jsonpath intra joins (joining parts of the same column)

Jsonpath version is the fastest, since it has its own executor, no overheads.
BUT it is primitive (uses only nested loop) and it wins only by chance.

- Counterexample:

```
create table jb_test as (select jsonb_build_object('id', i/1000, 'a',
jsonb_agg((random()*1000000)::int), 'b',
jsonb_agg((random()*1000000)::int)) jb from generate_series(0,999999) i
group by i/1000);

select jb->'id' from jb_test where jsonb_path_match(jb, '$.a[*] == $.b[*]'); – 13 sec

select jb->'id' from jb_test j where exists(
select 1 from jsonb_array_elements(j.jb->'a') a,
jsonb_array_elements(j.jb->'b') b
where a.value = b.value);  – 178 sec
```

BUT, we have choice
– hash join — 830 ms !
– merge join – 4250 ms

Why jsonpath at all ?

- It is **standard** query language for json
- It is **flexible** and **concise,** arrow operators are too primitive
    - Can be very useful for COPY and indexing json
- It is **faster** for complex processing

Roadmap (see Addendums)

- PG13: SQL/JSON functions from SQL-2016 standard
- PG13: datetime support in JSON Path (complete T832) – committed
- 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
- Make one JSON data type !

NoSQL Postgres rulezz !
Good Roadmap !
Who need Mongo ?

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 useful (standard, flexible, concise, sometimes fast)

Move from NoSQL to Postgres !

References

1)This talk: http://www.sai.msu.su/~megera/postgres/talks/jsonpath-pgconfeu-2019.pdf

2)Technical Report (SQL/JSON) - available for free
http://standards.iso.org/i/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip

3)Gentle introduction to JSON Path in PostgreSQL
https://github.com/obartunov/sqljsondoc/blob/master/jsonpath.md

4)Jsquery extension: https://github.com/postgrespro/jsquery/tree/sqljson
http://www.sai.msu.su/~megera/postgres/talks/pgconfeu-2014-jsquery.pdf

5)Play online with jsonpath
http://sqlfiddle.postgrespro.ru/#!21/0/2379

6)Parameters for opclasses
http://www.sai.msu.su/~megera/postgres/talks/opclass_pgconf.ru-2018.pdf

7)IMDB tables: http://www.sai.msu.su/~megera/postgres/files/imdb/imdb/

NOSQL POSTGRES IS A COMMUNITY PROJECT

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ALL
YOU
NEED
POSTGRES
IS

ADDENDUM I

SQL/JSON FUNCTIONS

SQL/JSON FUNCTIONS

- 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()

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

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)
```

ADDENDUM II

Parameters for Opclasses

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**)

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

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'));
```

ADDENDUM III

Planner support for jsonpath

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 !)

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)
```

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
```

ADDENDUM IV

Jsonpath syntax extensions

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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
```

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"
```

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)'`

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
```

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;
```

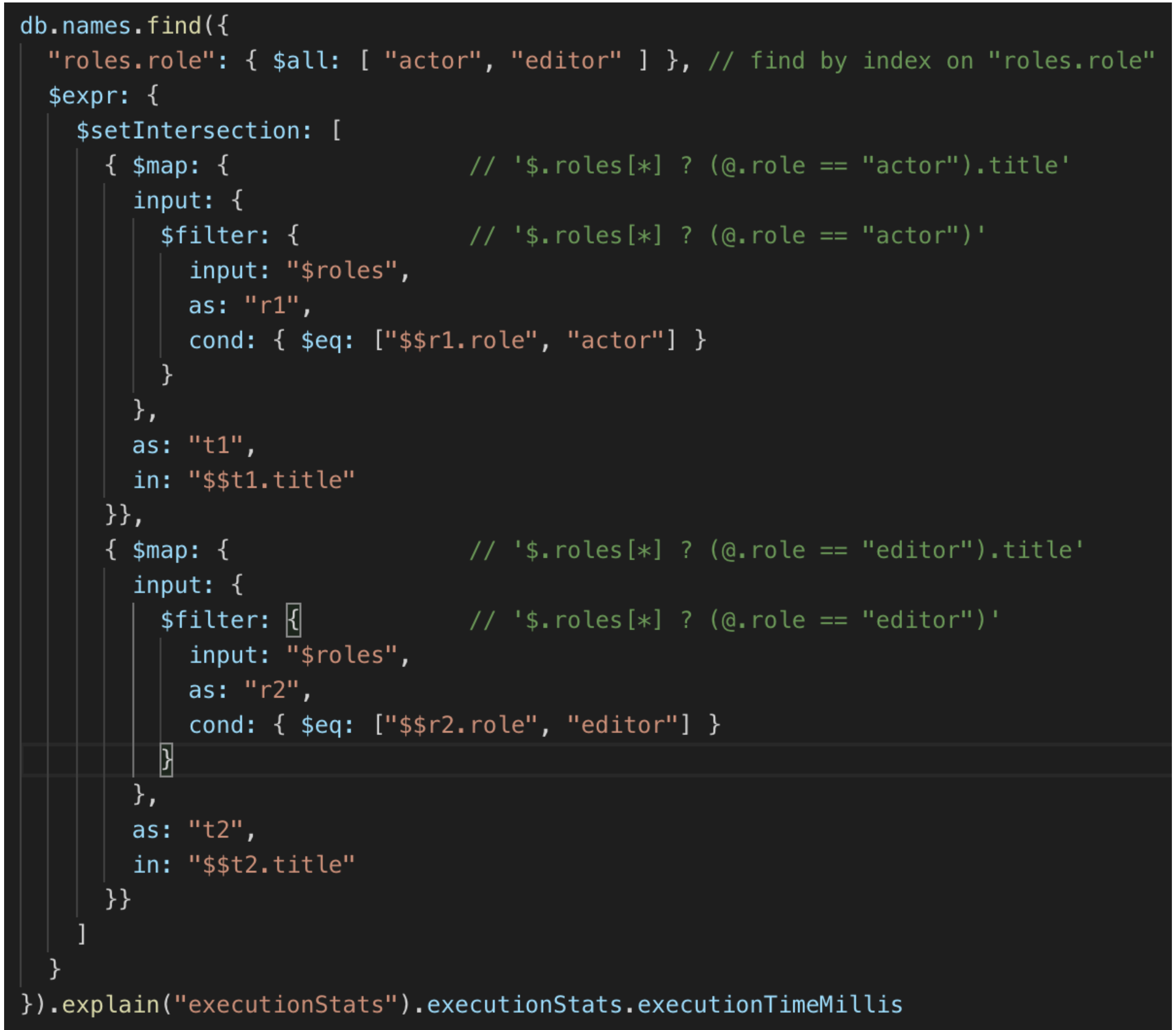
ADDENDUM V

Performance of Intra joins

Jsonpath intra joins (joining parts of the same column)

mongoDB

3808 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
```

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:              13745.517 ms
Bitmap Index Scan(parallel,6):  3807.380 ms
```

ADDENDUM VI

Two floors house

```
CREATE TABLE house(js) AS SELECT jsonb '
{
  "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}
      ]
    }
  ]
}

';
```