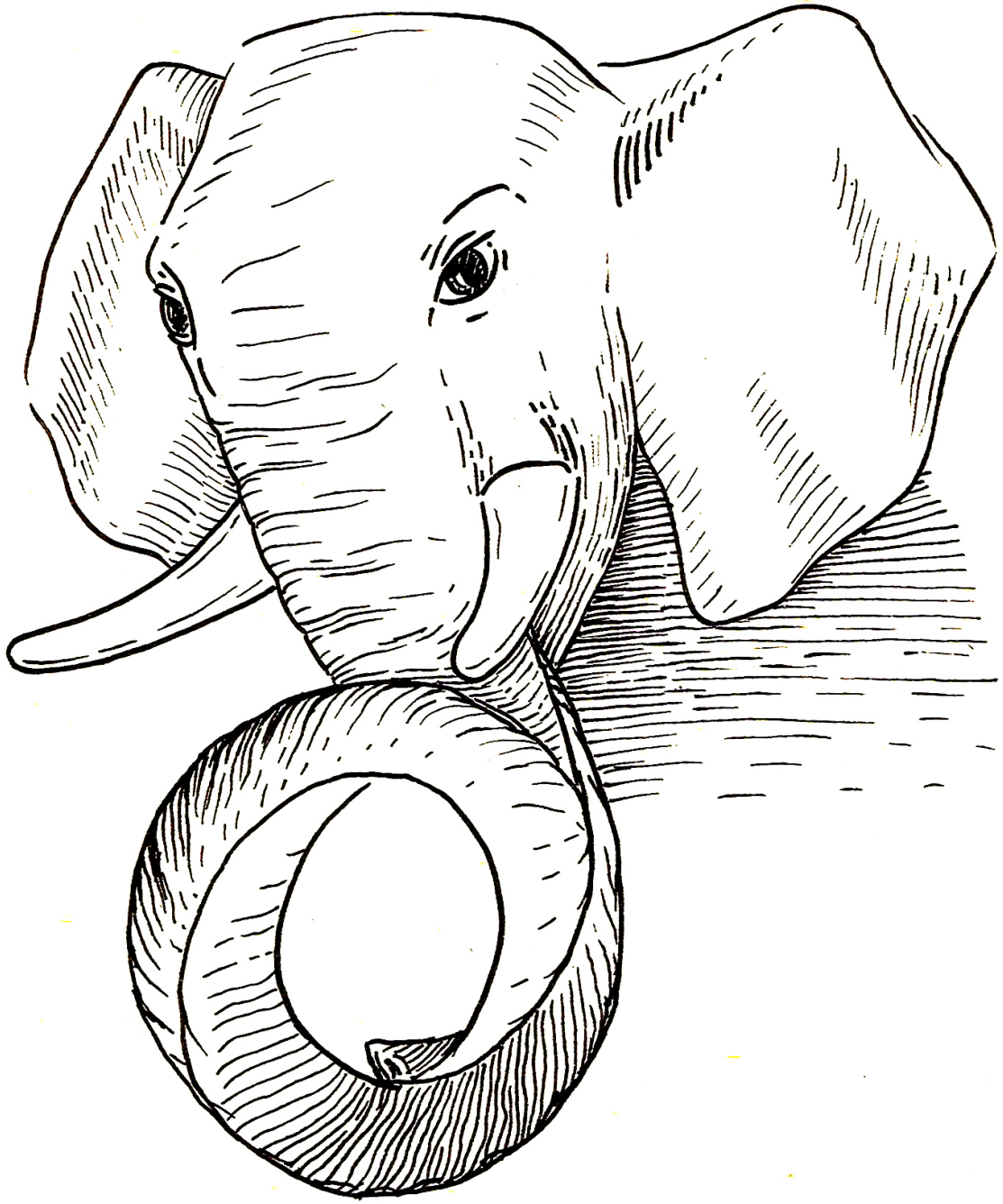
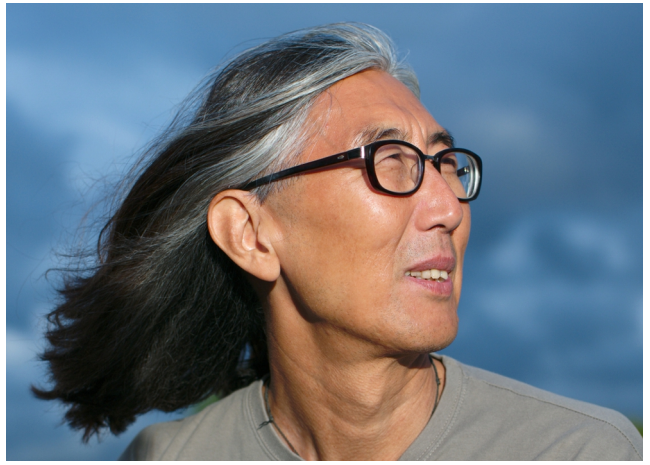


Jsonb roadmap

Oleg Bartunov
Postgres Professional



Oleg Bartunov

Major PostgreSQL contributor

CEO, Postgres Professional

Moscow University

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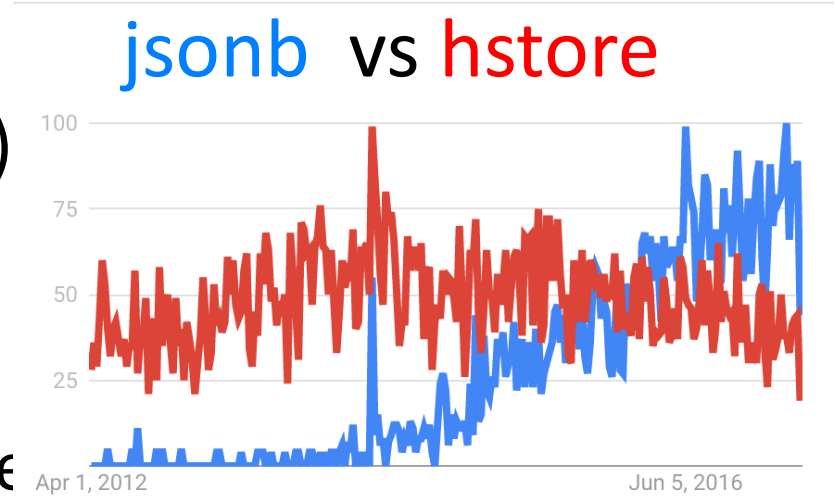
Since 1995

NoSQL Postgres briefly

- 2003 — hstore (sparse columns, schema-less)
- 2006 — hstore as demo of GIN indexing, 8.2 release
- 2012 (sep) — JSON in 9.2 (verify and store)
- 2012 (dec) — nested hstore proposal
- 2013 — PGCon, Ottawa: nested hstore
- 2013 — PGCon.eu: binary storage for nested data
- 2013 (nov) — nested hstore & jsonb (better/binary)
- 2014 (feb-mar) — forget nested hstore for jsonb
- Mar 23, 2014 — jsonb committed for 9.4
- 2014 (apr) — hstore_ops, better gin index for hstore



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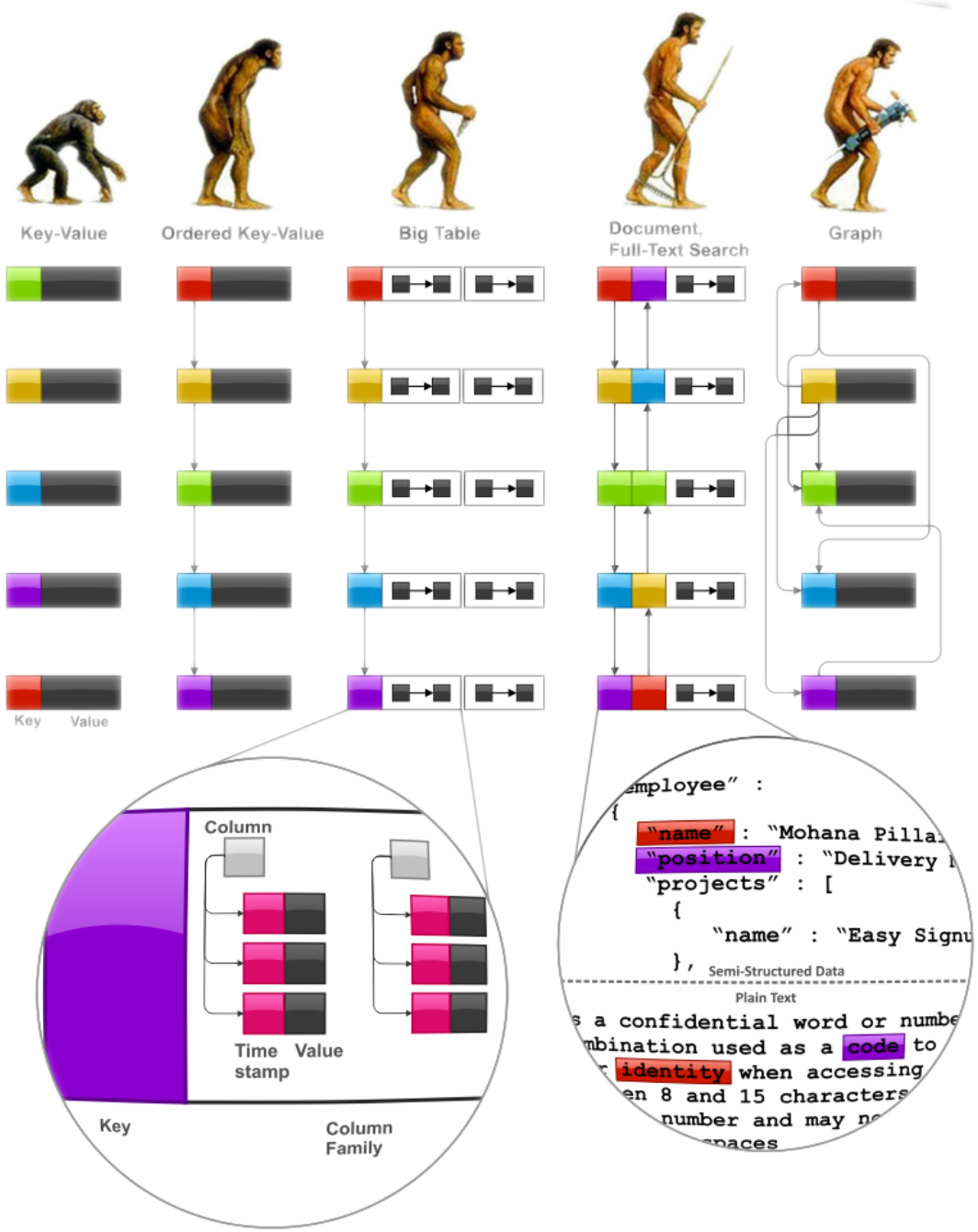

PostgreSQL 9.4: NoSQL on ACID

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

JSON - 2012
- Textual storage
- JSON verification

HSTORE - 2003
- Perl-like hash storage
- No nesting
- Indexing

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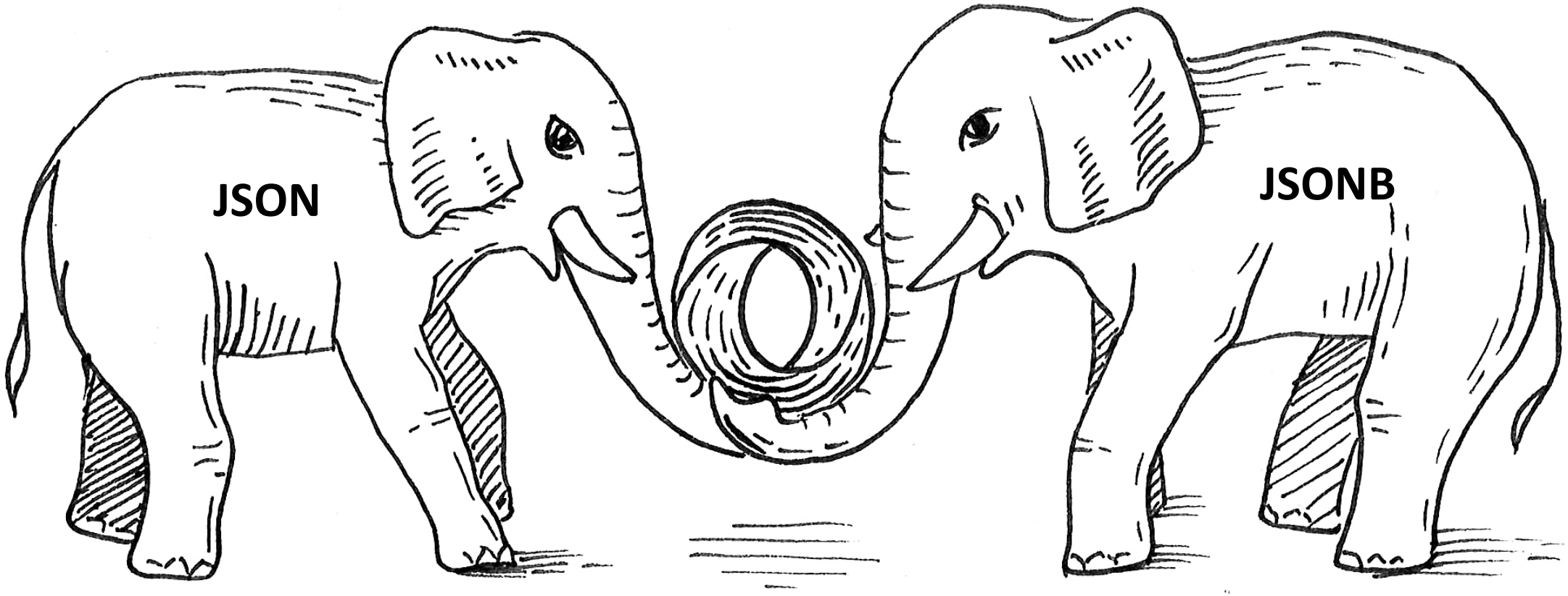
Two JSON data types !!!

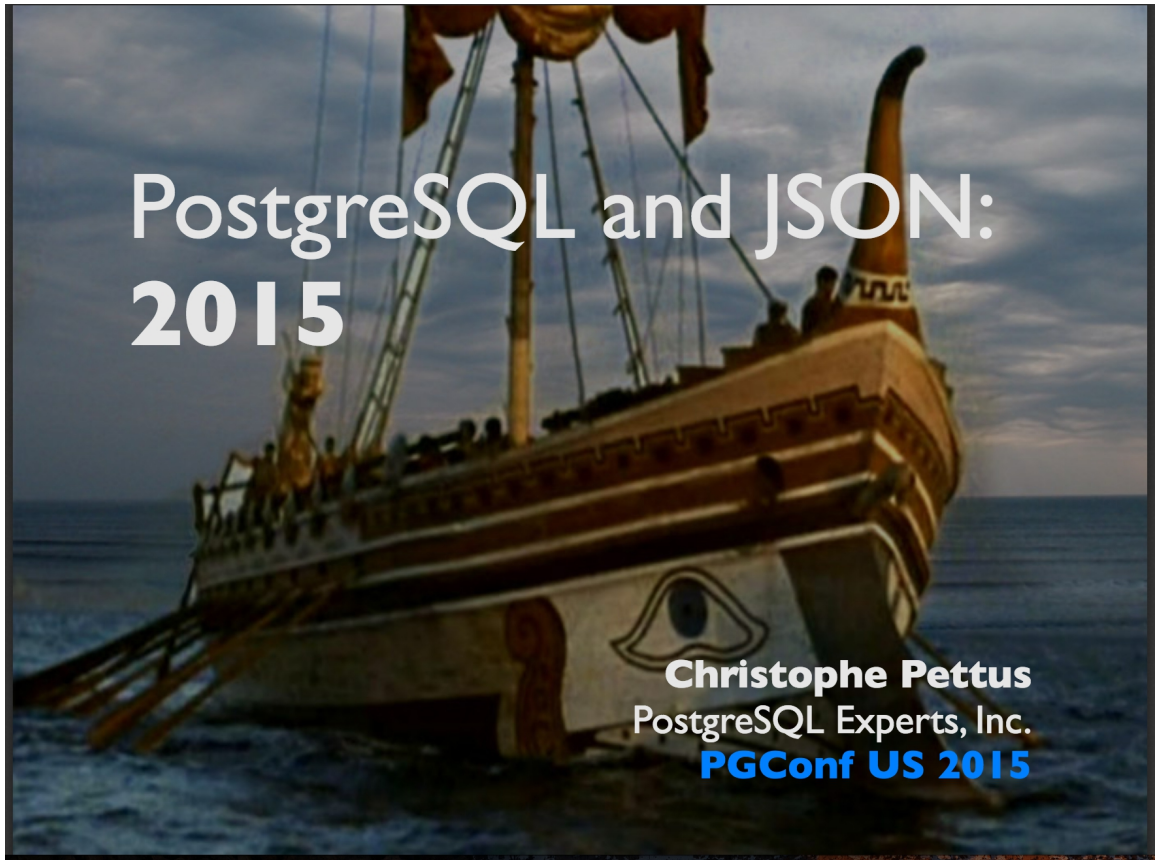


Jsonb vs Json

```
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)
- A rich set of functions to work with jsonb (\df jsonb*)

Very detailed talk about JSON[B]



http://thebuild.com/presentations/json2015-pgconfus.pdf

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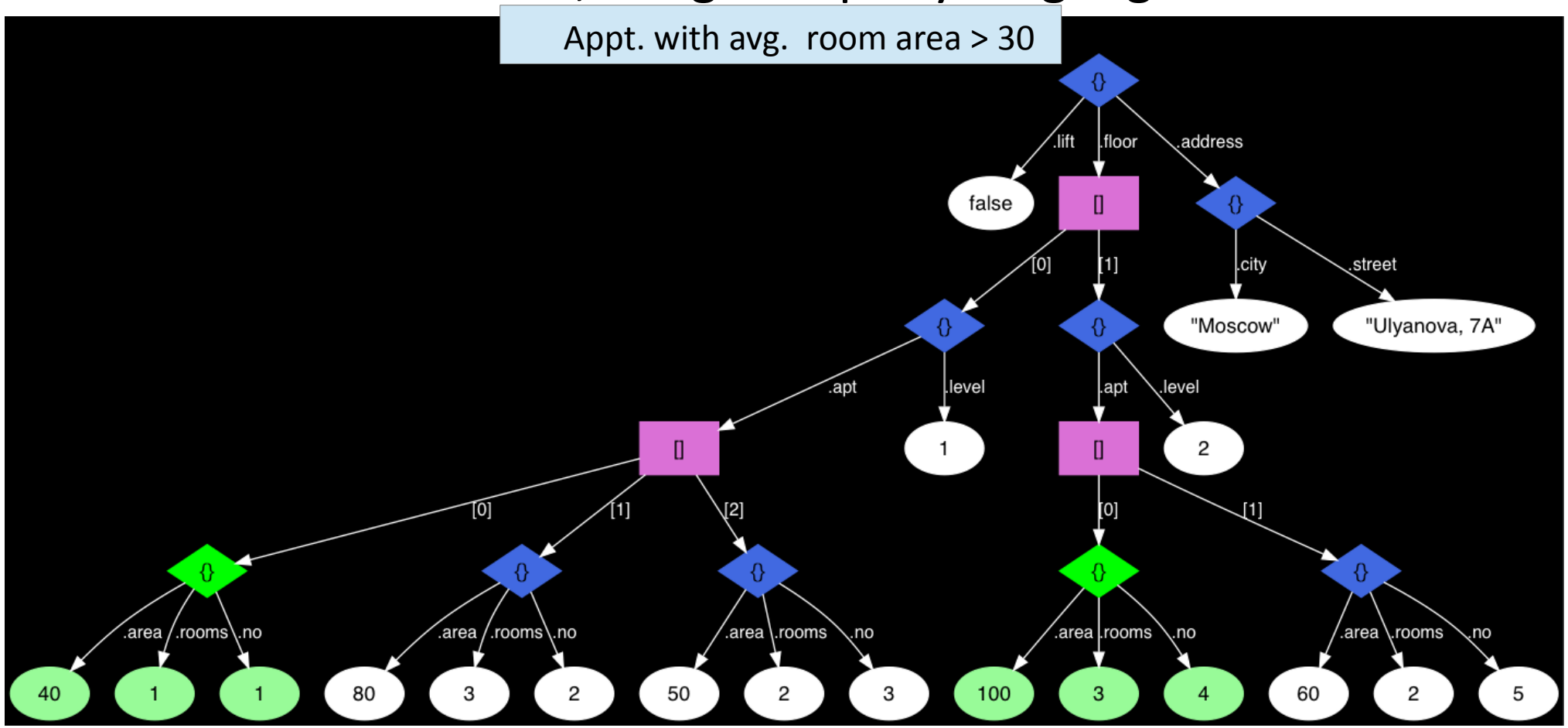
JSONB is great, BUT

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



Find something «red»

```
      Table "public.js_test"
 Column |  Type   | Modifiers
--------+---------+-----------
 id     | integer | not null
 value  | jsonb   |

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}], "colr": "red"}
  8 | {"a": "blue", "t": [{"color": "green", "width": 100}]}
  9 | {"color": "green", "value": "red", "width": 100}
(9 rows)
```

Find something «red»

- VERY COMPLEX SQL QUERY

```
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;
```

```
 id |                                                                value
----+-------------------------------------------------------------------------
  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"}
(5 rows)
```

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PGCon-2014, Ottawa

Find something «red»

```
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;
```

- **Jsquery**

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

https://github.com/postgrespro/jsquery

- A language to query jsonb data type
- Search in nested objects and arrays
- More comparison operators with indexes support

JSONB is great, BUT

1) JSONB is a «black box» for SQL, no good query language

2) There is no SQL way to update JSONB, jsonb_set() does the job

UPDATE table_name SET doc{key} = value – not supported

3) JSONB is a «fat» data type — keys could be up to 2^28, 256 Mb !

«looooooooooooooooooooooooong_key1»:1,
«veeeeeeeeery_looooooooooooooooooooooong_key2»:2

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JSON in SQL-2016

JSON in SQL-2016

- ISO/IEC 9075-2:2016(E) - https://www.iso.org/standard/63556.html
- BNF https://github.com/elliotchance/sqltest/blob/master/standards/2016/bnf.txt
- Discussed at Developers meeting Jan 28, 2017 in Brussels
- Post -hackers, Feb 28, 2017 (March commitfest)
  «Attached patch is an implementation of SQL/JSON data model from SQL-2016 standard (ISO/IEC 9075-2:2016(E)), which was published 2016-12-15 ...»
- Patch was too big (now about 16,000 loc) and too late for Postgres 10 :(

SQL/JSON in PostgreSQL

- SQL Standard describes XML data type, but not JSON data type
- SQL/JSON describes a JSON data model for SQL, uses string to store

- PostgreSQL implementation uses native data types
  - JSON, JSONB as ORDERED and UNIQUE KEYS
  - jsonpath data type for SQL/JSON path language
  - nine functions, implemented as SQL CLAUSEs

SQL/JSON in PostgreSQL

- **Jsonpath** provides an ability to operate (in standard specified way) with json structure at SQL-language level
  - Dot notation — $.a.b.c
  - $ - the current context element
  - Array - [*]
  - Filter ? - $.a.b.c ? (@.x > 10)
  - @ - current context in filter expression
  - Methods - $.a.b.c.x.type()
    - type(), size(), double(), ceiling(), floor(), abs(), datetime(), keyvalue()

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

Why JSON path is a type ?

Standard permits only string literals in JSON path specification.

WHY a data type ?

- 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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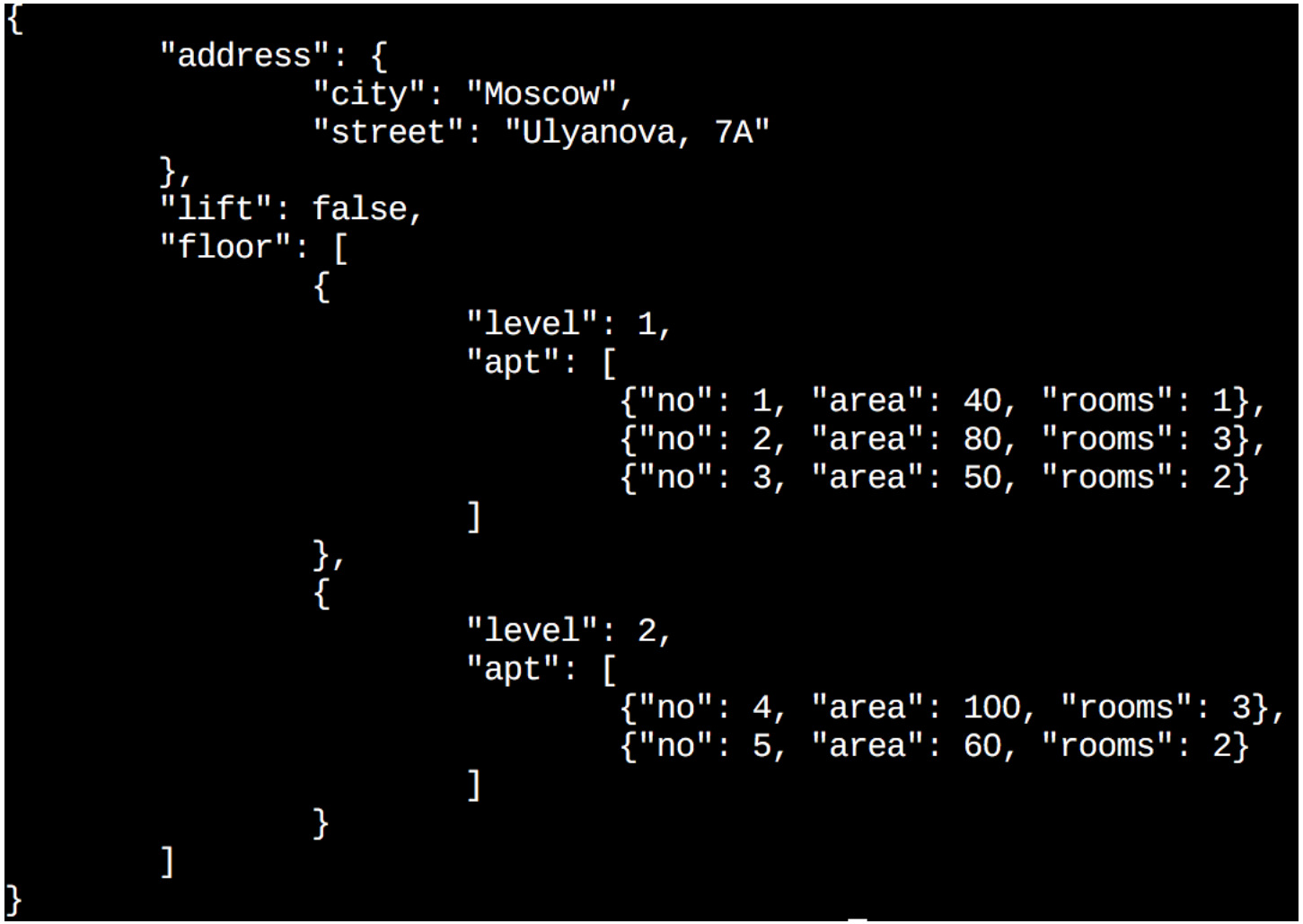
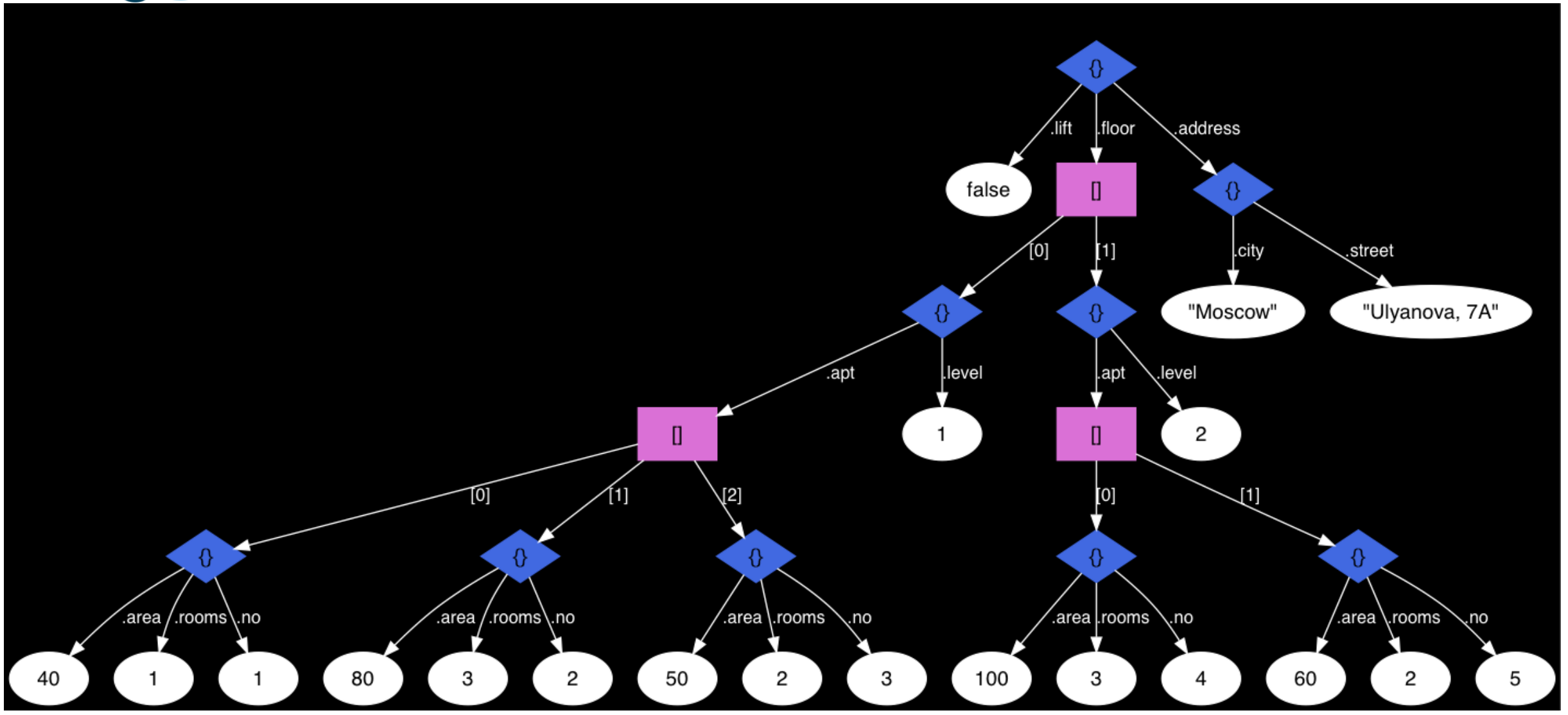
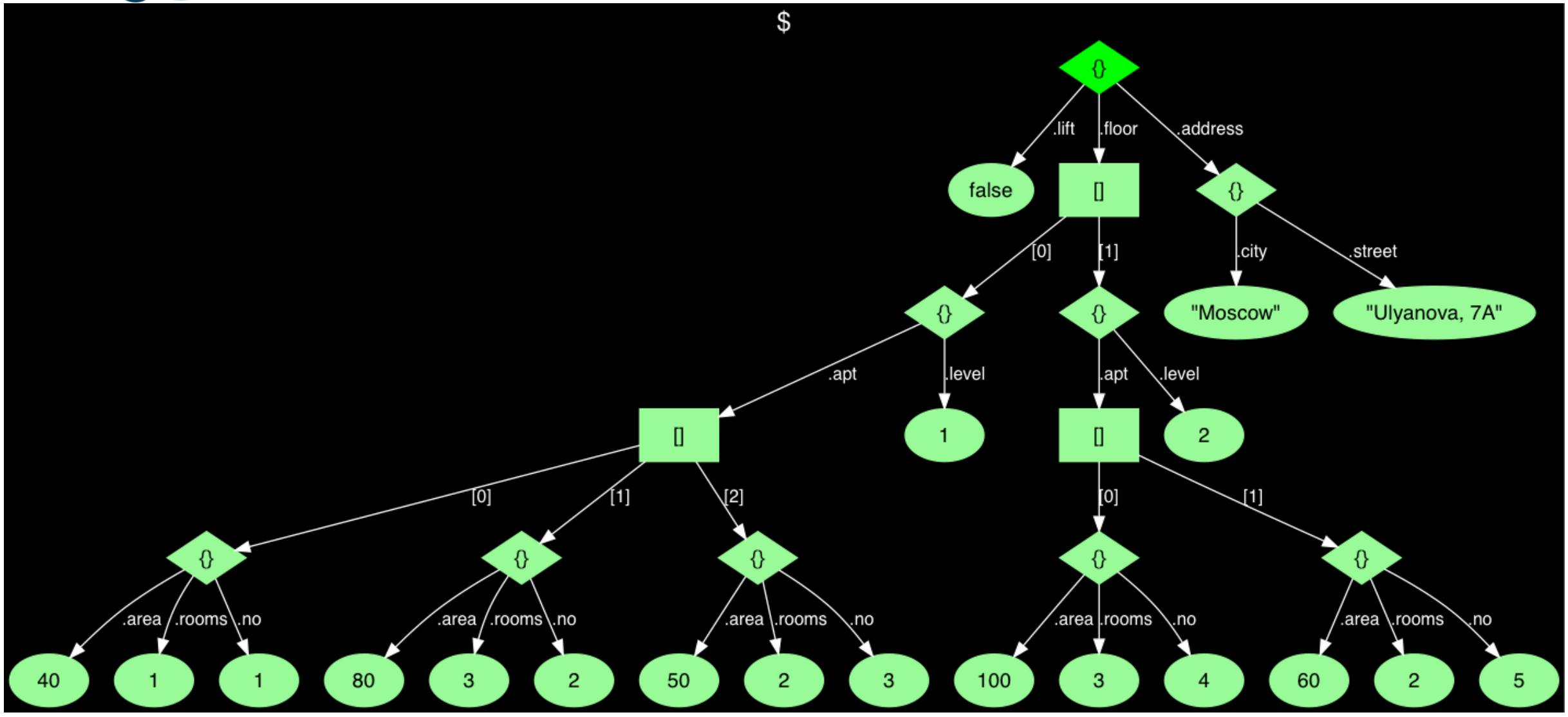
Visual guide on jsonpath



2-floors house



Everything


$
{}
.lift
.floor
.address
false
[]
{}
[0]
[1]
.city
.street
"Moscow"
"Ulyanova, 7A"
{}
{}
.apt
.level
.apt
.level
[]
1
[]
2
[0]
[1]
[2]
[0]
[1]
{}
{}
{}
{}
{}
.area
.rooms
.no
.area
.rooms
.no
.area
.rooms
.no
.area
.rooms
.no
.area
.rooms
.no
40
1
1
80
3
2
50
2
3
100
3
4
60
2
5

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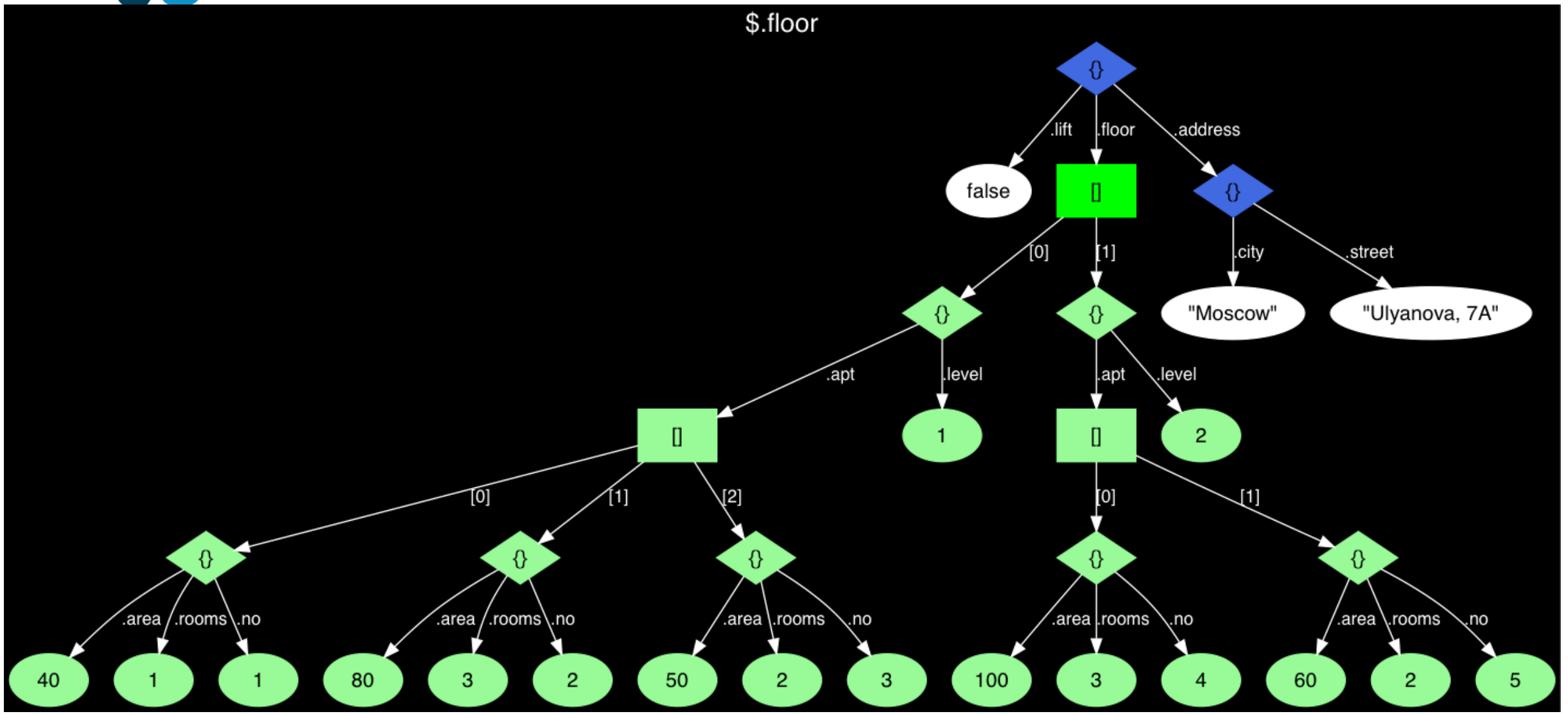
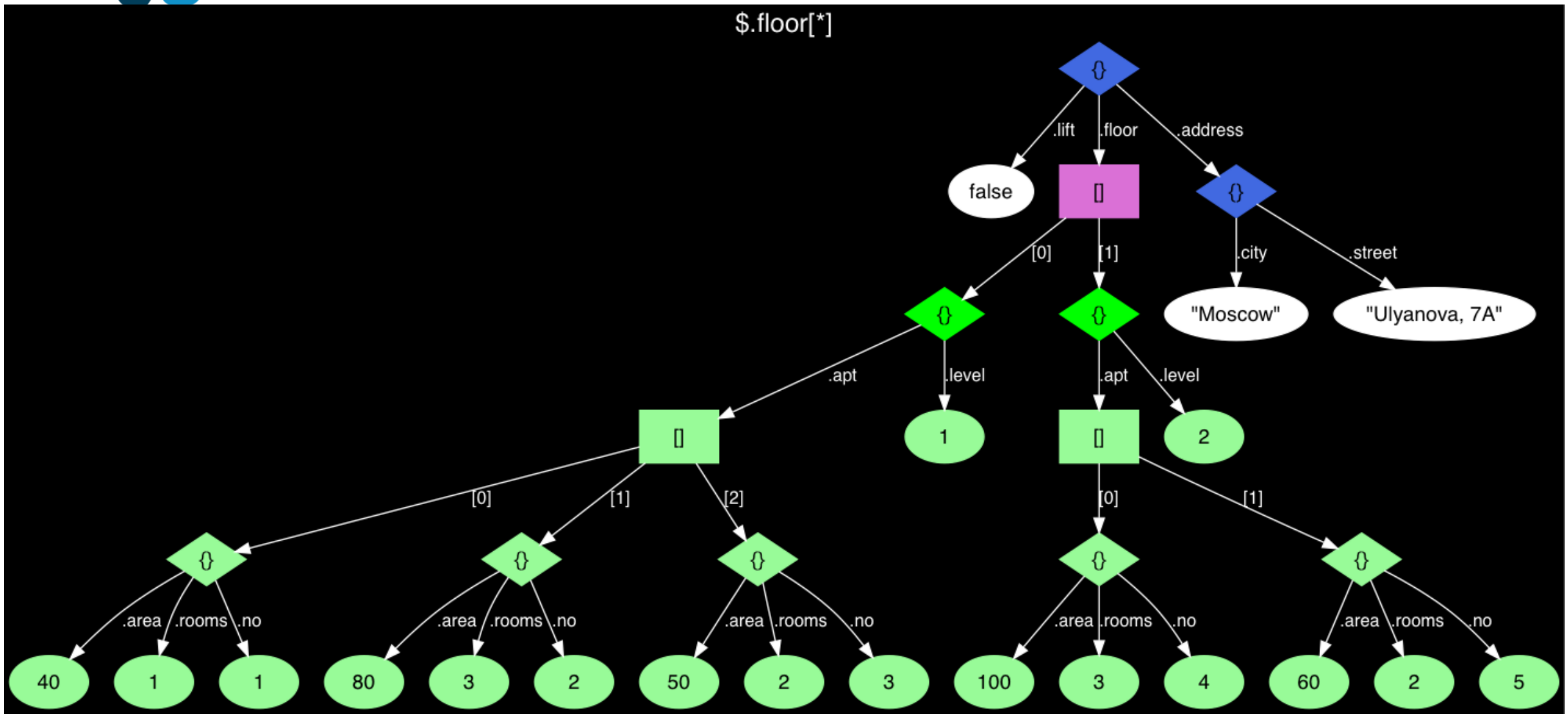
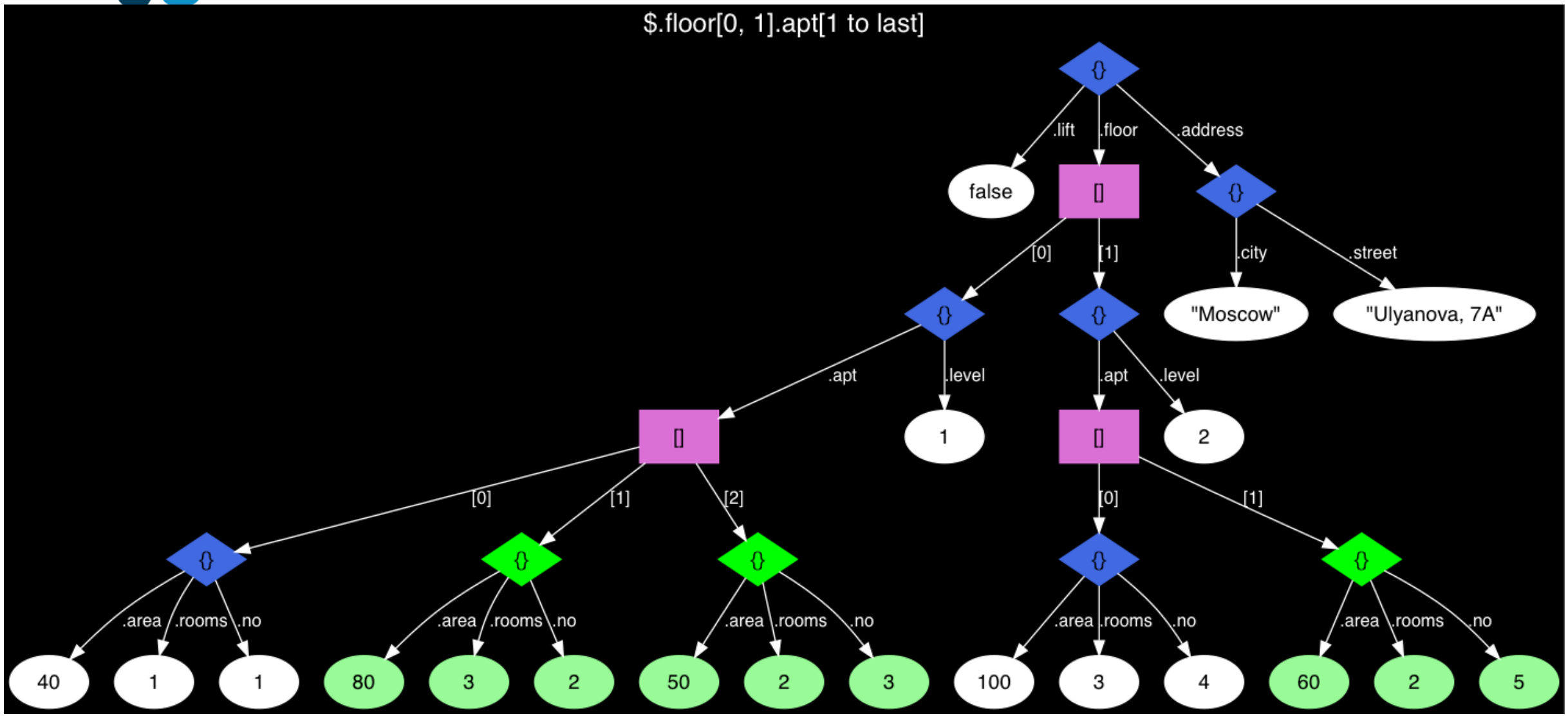
[Floors]



PROFESSIONAL Postgres



PROFESSIONAL Postgres



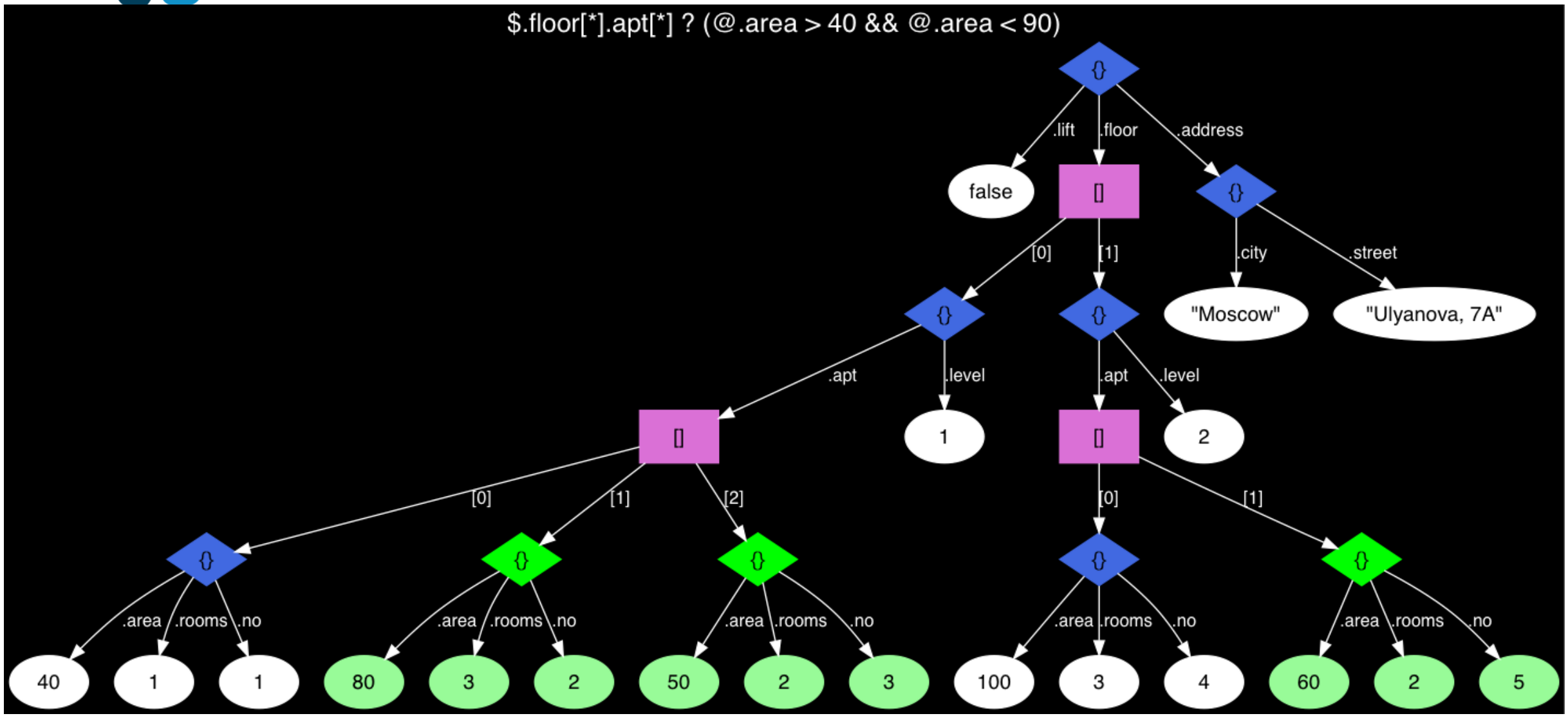
$.floor[0, 1].apt[1 to last]

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

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

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);
```

PROFESSIONAL Postgres



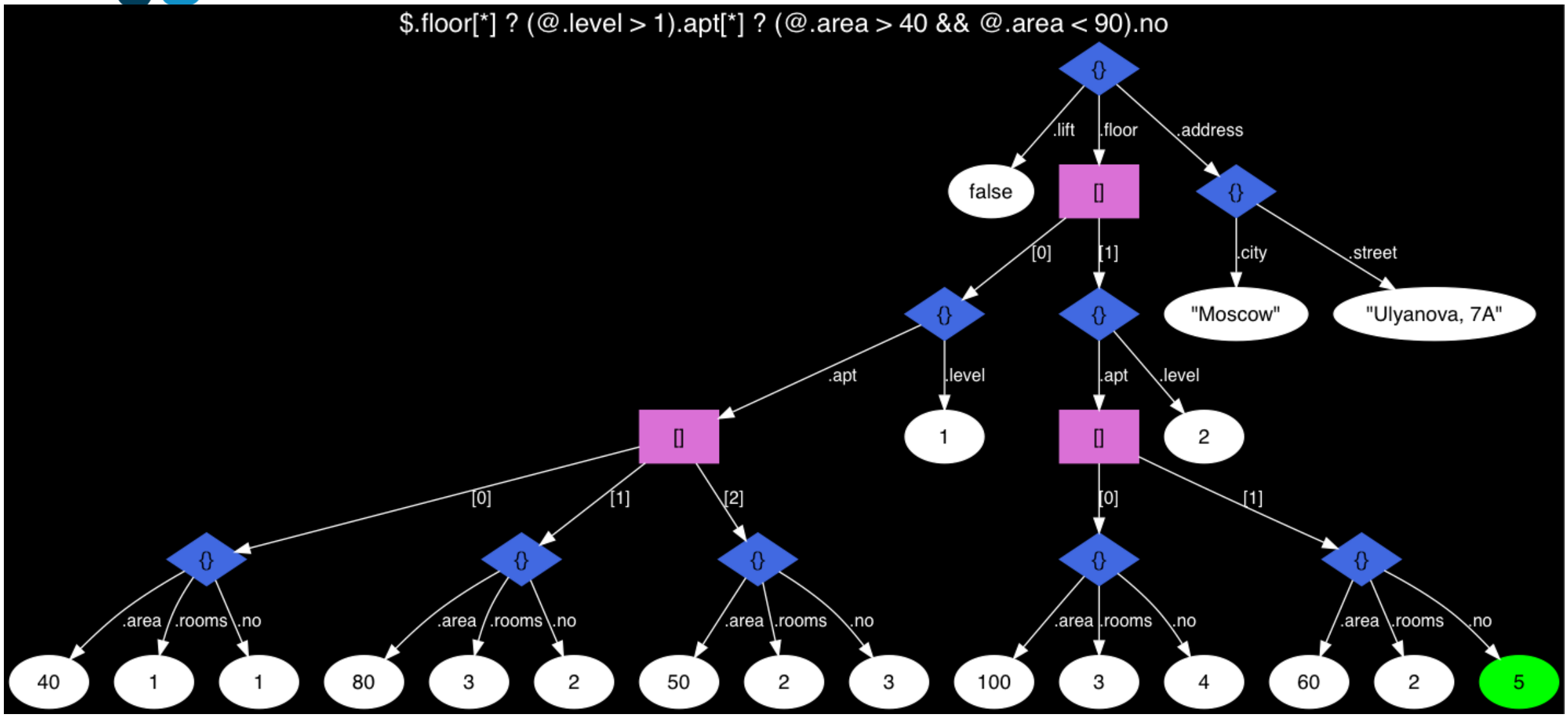
$.floor[*].apt[*] ? (@.area > 40 && @.area < 90)

```
SELECT JSON_QUERY(js, '$.floor[*].apt[*] ? (@.area > $min && @.area < $max)'
PASSING 40 AS min, 90 AS max WITH WRAPPER) FROM house;

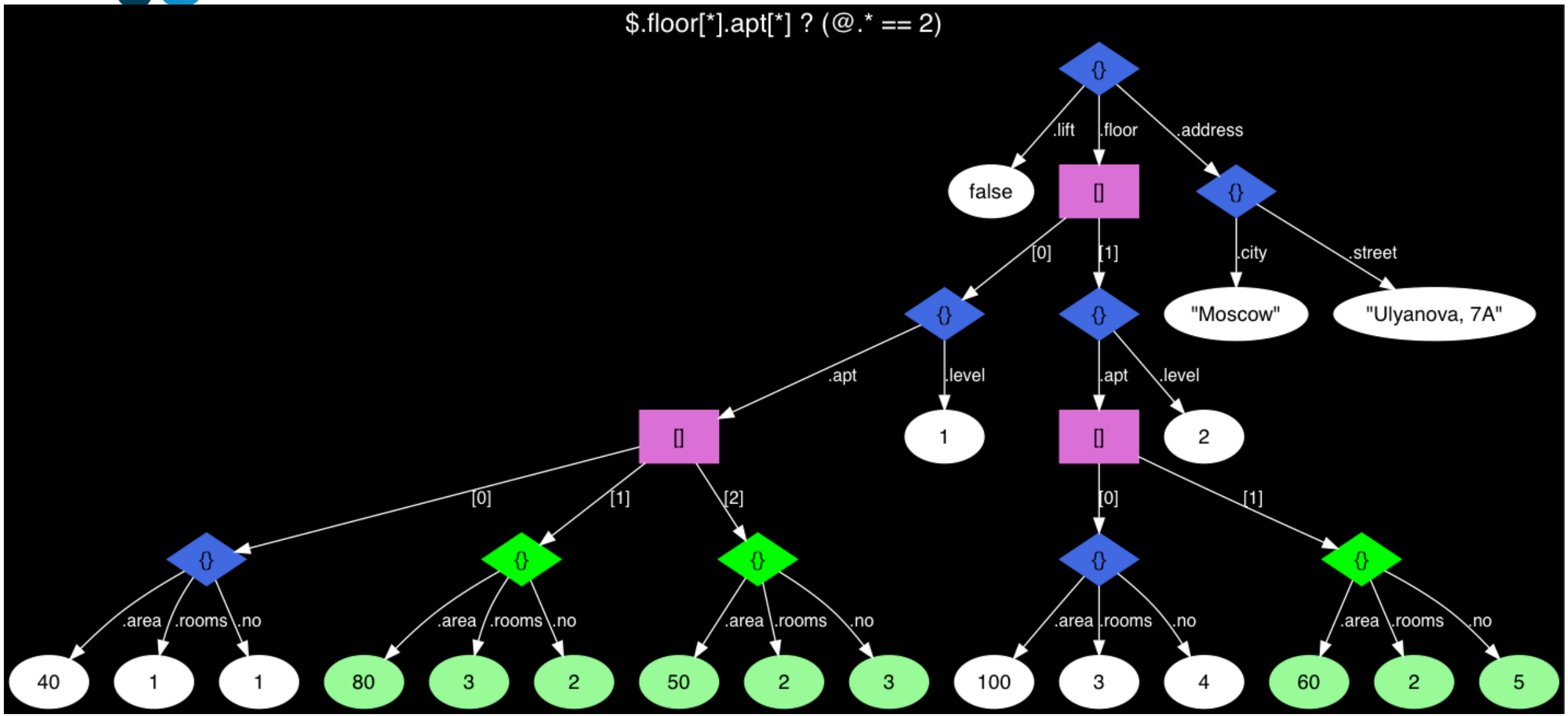
SELECT apt
FROM (SELECT jsonb_array_elements(jsonb_array_elements(js->'floor')->'apt')
      FROM house) apts(apt)
WHERE (apt->>'area')::int > 40 AND (apt->>'area')::int < 90;

SELECT jsonb_agg(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;
```

PROFESSIONAL Postgres



PROFESSIONAL Postgres

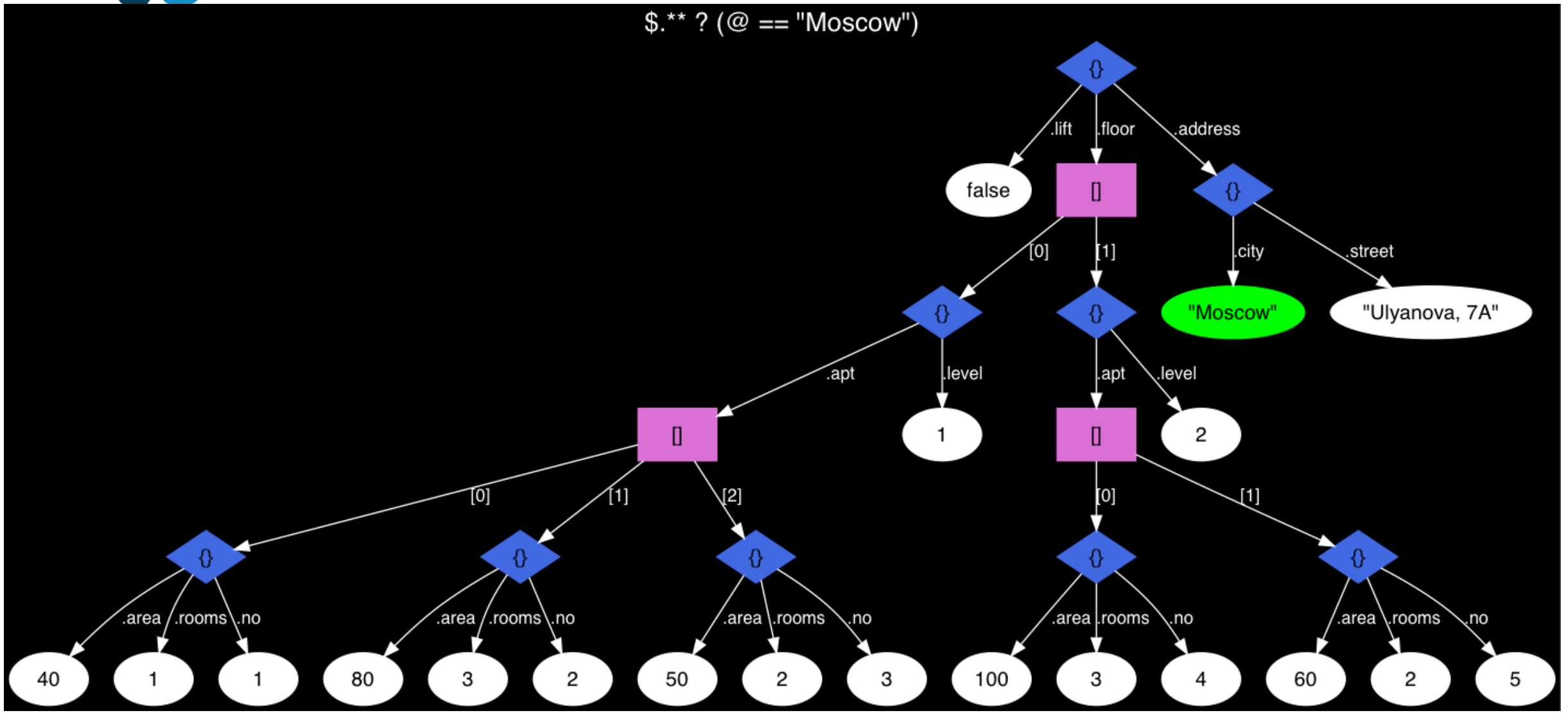


$.floor[*].apt[*] ? (@.* == 2)

```
SELECT JSON_QUERY(js, '$.floor[*].apt[*] ? (@.* == 2)' WITH WRAPPER) FROM house;

SELECT apt
FROM (SELECT jsonb_array_elements(jsonb_array_elements(js->'floor')->'apt')
      FROM house) apts(apt)
WHERE '2' = ANY(SELECT (jsonb_each(apt)).value);
```

Extension: wildcard search

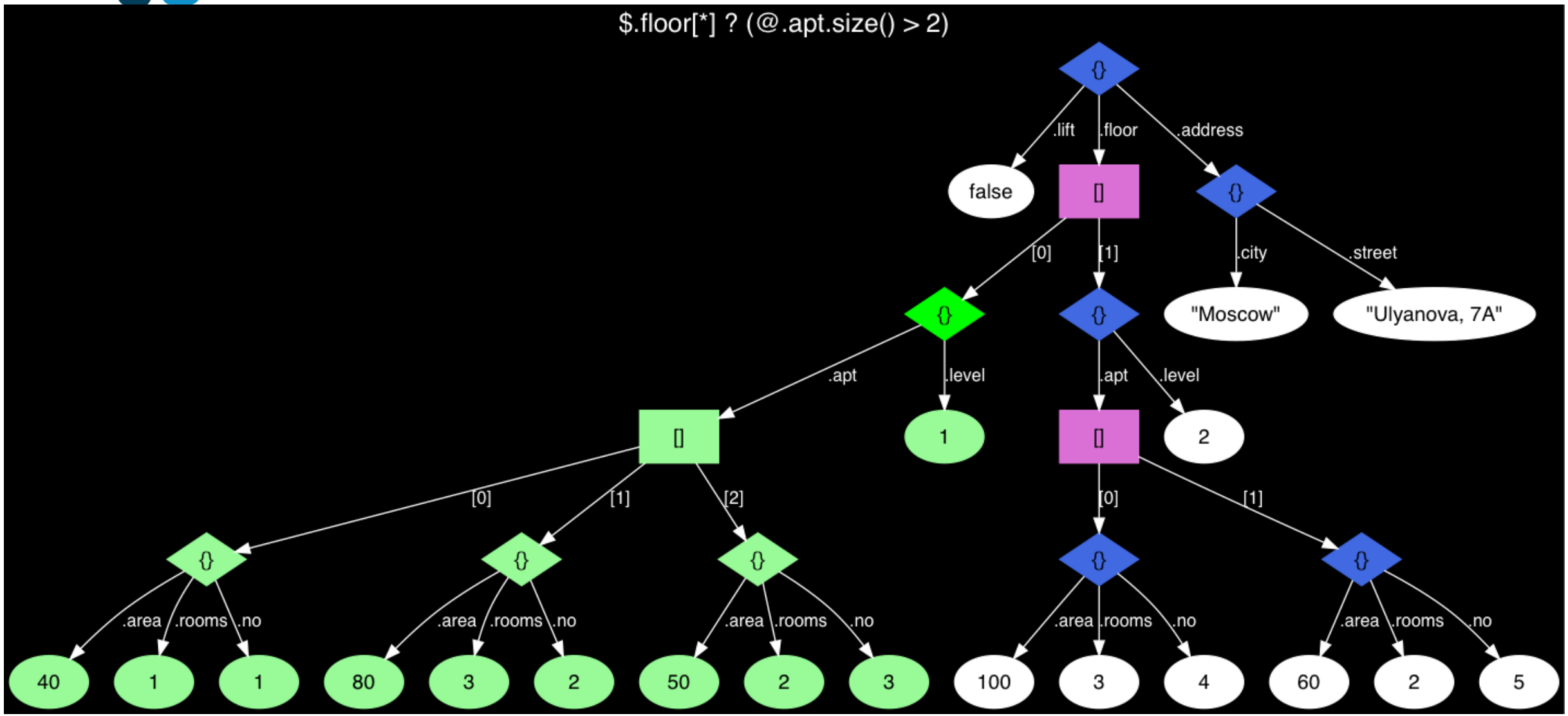


$.** ? (@ == "Moscow")

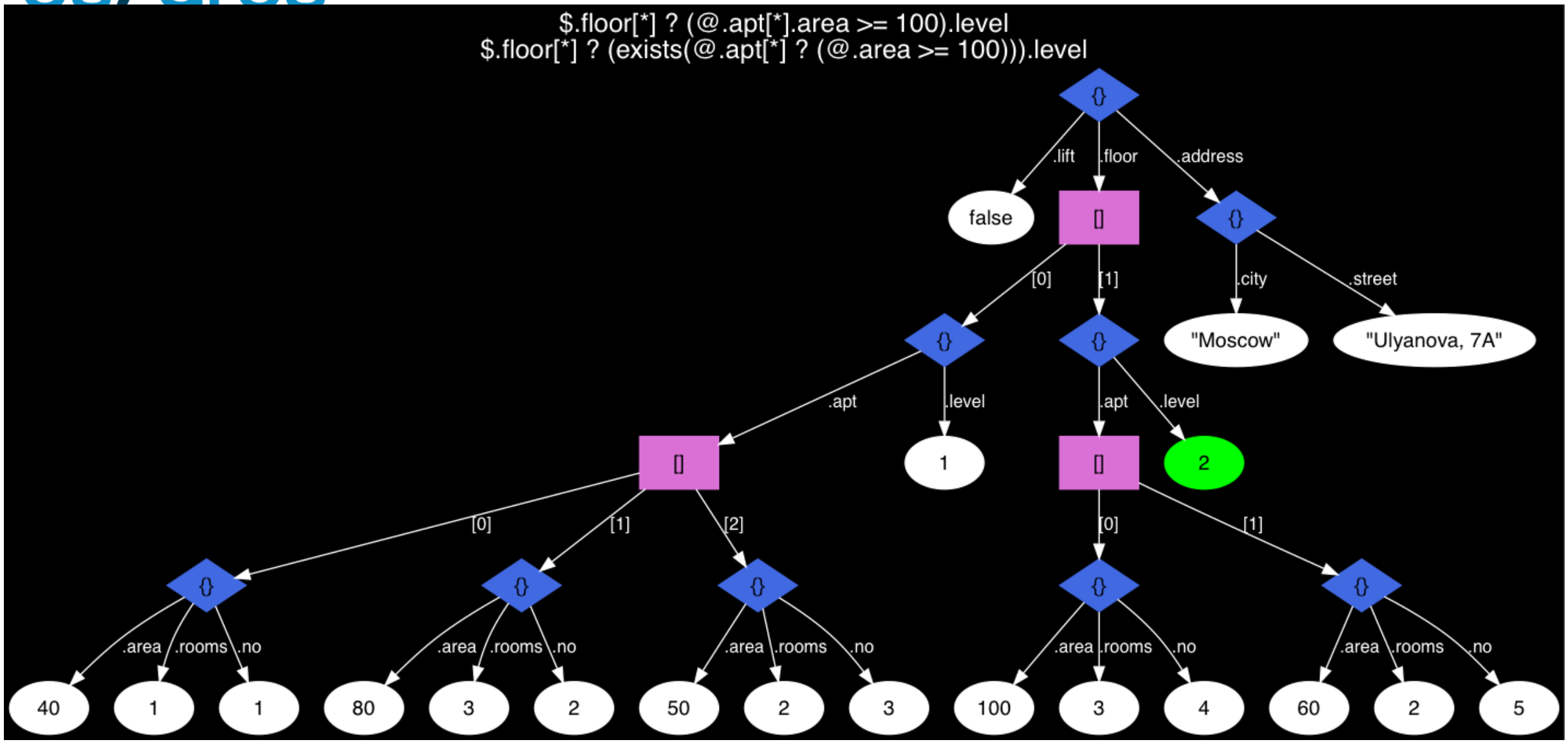
```
SELECT JSON_EXISTS(js, '$.** ? (@ == "Moscow")') FROM house;

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"');
```

PROFESSIONAL Postgres



PROFESSIONAL Postgres



Find something «red»

- ```
  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;
```

- Jsquery

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

- **SQL/JSON 2016**

```
SELECT * FROM js_test WHERE
JSON_EXISTS( value,'$.**.color ?
(@ == "red")');
```
```

JSON PATH is COOL !

Postgres PROFESSIONAL

JSON PATH is COOL !
Let“s Extend it !
JSON[b] OP JSONPATH

jsonpath operators: exists

- Exists: `json[b] @? jsonpath` returns `bool`.

```
SELECT '{"foo": [1,2,3]}'::jsonb @? '$.foo[*] ? (@ > 2)';
 ?column?
----------
 t
(1 row)

SELECT '{"foo": [1,2,3]}'::jsonb @? '$.foo[*] ? (@ > 3)';
 ?column?
----------
 f
(1 row)
```

jsonpath operators: match

- Match: `json[b] @~ jsonpath` returns `bool`.
  Root expression must be a predicate (extension of the standard).

```
SELECT '{"foo": [1,2,3]}'::jsonb @~ '$.foo[*] > 2';
 ?column?
----------
 t
(1 row)

SELECT '{"foo": [1,2,3]}'::jsonb @~ '$.foo[*] > 3';
 ?column?
----------
 f
(1 row)
```

jsonpath operators: query

- Query: `json[b] @* jsonpath` returns `setof json[b]`.

```
SELECT '{"foo": [1,2,3]}'::jsonb @* '$.foo[*] ? (@ > 1)';

 ?column?
----------
 2
 3
(2 rows)
```

jsonpath operators

- jsonb @? jsonpath and jsonb @~ jsonpath are fast as jsonb @> jsonb (for equality operation)
- But, jsonpath supports more complex expressions:
  Delicious bookmarks dataset

```
SELECT COUNT(*) FROM bookmarks
WHERE jb @~ '$.updated.datetime("Dy, dd MON YYYY
HH24:MI:SS") > "2009-09-11".datetime("YYYY-MM-DD")';
 Count
--------
 484341
(1 row)
```

jsonpath operators: index support

- Exists @? and match @~ operators can be speeded up by GIN index using built-in jsonb_ops or jsonb_path_ops.

```
SELECT COUNT(*) FROM bookmarks
WHERE jb @? '$.tags[*] ? (@.term == "NYC")';
                                                                  QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------------
 Aggregate (actual time=0.529..0.529 rows=1 loops=1)
   ->  Bitmap Heap Scan on bookmarks (actual time=0.080..0.502 rows=285 loops=1)
         Recheck Cond: (jb @? '$."tags"[*]?(@."term" == "NYC")'::jsonpath)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on bookmarks_jb_path_idx (actual time=0.045..0.045
rows=285 loops=1)
               Index Cond: (jb @? '$."tags"[*]?(@."term" == "NYC")'::jsonpath)
 Planning time: 0.053 ms
 Execution time: 0.553 ms
(8 rows)
```

jsonpath operators: index support

- Exists @? and match @~ operators can be accelerated by GIN index using built-in jsonb_ops or jsonb_path_ops.

```
SELECT COUNT(*) FROM bookmarks
WHERE jb @~ '$.tags[*].term == "NYC"';
                                                    QUERY PLAN
-------------------------------------------------------------------------------------------------------------------
Aggregate (actual time=0.930..0.930 rows=1 loops=1)
   ->  Bitmap Heap Scan on bookmarks (actual time=0.133..0.884 rows=285 loops=1)
         Recheck Cond: (jb @~ '($."tags"[*]."term" == "NYC")'::jsonpath)
         Heap Blocks: exact=285
         ->  Bitmap Index Scan on bookmarks_jb_path_idx (actual time=0.073..0.073
rows=285 loops=1)
               Index Cond: (jb @~ '($."tags"[*]."term" == "NYC")'::jsonpath)
 Planning time: 0.135 ms
 Execution time: 0.973 ms
(8 rows)
```

Jsonpath operators: joins by index

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

```
SELECT JSON_VALUE(b1.jb, '$.author')
FROM bookmarks b1, bookmarks b2
WHERE JSON_EXISTS(b1.jb,
   '$ ? (@.title  == $bookmark.title &&
         @.author != $bookmark.author)' PASSING b2.jb AS bookmark) AND
      JSON_VALUE(b2.jb, '$.author') = 'ant.on';
```

SEQ.SCAN: 6.7 sec

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

```
create index bookmarks_jb_path_idx on bookmarks using gin(jb  jsonb_path_ops );
```

INDEX SCAN: 0.2 ms **33500 times faster !**

JSON PATH is COOL !

SQL/JSON in PostgreSQL

- The SQL/JSON **construction** functions:

Mostly the same as json[b] construction 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: JSON_OBJECT

JSON_OBJECT - construct a JSON[b] object.

Syntax:

```
JSON_OBJECT (
  [ { expression {VALUE | ':'} json_value_expression }[,…] ]
  [ { NULL | ABSENT } ON NULL ]
  [ { WITH | WITHOUT } UNIQUE [ KEYS ] ]
  [ RETURNING data_type [ FORMAT JSON ] ]
)
```

```
json_value_expression ::=
    expression [ FORMAT JSON ]
```

SQL/JSON: JSON_OBJECT

- Internally transformed into a json[b]_build_object() call
- RETURNING type:
  - Json by default
  - can be json, jsonb, string type, bytea or having cast from json
  - determines which function to use:

    jsonb => jsonb_build_object

    other => json_build_object
- There are two additional options:
  - key uniqueness check: `{WITH|WITHOUT} UNIQUES [KEYS]`
  - ability to omit keys with NULL values: `{ABSENT|NULL} ON NULL`

SQL/JSON: JSON_OBJECT

Key uniqueness check (disabled by default):

```
SELECT JSON_OBJECT('a': 1, 'a': 2 WITH UNIQUE KEYS);
ERROR: duplicate JSON key "a"

SELECT JSON_OBJECT('a': 1, 'a': 2);
      ?column?
--------------------
 {"a" : 1, "a" : 2}
(1 row)

SELECT JSON_OBJECT('a': 1, 'a': 2 RETURNING jsonb);
 ?column?
----------
 {"a": 2}
(1 row)
```

SQL/JSON: JSON_OBJECT

Omitting keys with NULL values (keys themselves are not allowed to be NULL):

```
SELECT JSON_OBJECT('a': 1, 'b': NULL);
       ?column?
------------------------
 {"a" : 1, "b" : null}
(1 row)

SELECT JSON_OBJECT('a': 1, 'b': NULL ABSENT ON NULL);
 ?column?
-----------
 {"a" : 1}
(1 row)
```

SQL/JSON: JSON_OBJECTAGG

JSON_OBJECTAGG - aggregates name/value pairs as JSON[b] object.

Syntax:

```
JSON_OBJECTAGG (
  expression { VALUE | ':' } expression [ FORMAT JSON ]
  [ { NULL | ABSENT } ON NULL ]
  [ { WITH | WITHOUT } UNIQUE [ KEYS ] ]
  [ RETURNING data_type [ FORMAT JSON ] ]
)
```

Options and RETURNING clause are the same as in JSON_OBJECT.

SQL/JSON: JSON_OBJECTAGG

JSON_OBJECTAGG is transformed into a json[b]_object_agg depending on RETURNING type.

```
=# SELECT JSON_OBJECTAGG('key' || i : 'val' ||  i)
   FROM generate_series(1, 3) i;

                          ?column?
-------------------------------------------------------
 { "key1" : "val1", "key2" : "val2", "key3" : "val3" }
(1 row)
```

SQL/JSON: JSON_ARRAY

JSON_ARRAY - construct a JSON[b] array

```
JSON_ARRAY (
  [ { expression [ FORMAT JSON ] }[, ...] ]
  [ { NULL | ABSENT } ON NULL ]
  [ RETURNING data_type [ FORMAT JSON ] ]
)

JSON_ARRAY (
  query_expression
  [ RETURNING data_type [ FORMAT JSON ] ]
)
```

Note: ON NULL clause is not supported in subquery variant.

SQL/JSON: JSON_ARRAY

- Internally transformed into a json[b]_build_array() call
- RETURNING type:
  - json by default
  - can be json, jsonb, string type, bytea or having cast from json
  - determines which function to use:

    jsonb => jsonb_build_array

    other => json_build_array
- There is one additional option:
  - The ability to omit or keep elements with NULL values: `{ABSENT|NULL} ON NULL`

SQL/JSON: JSON_ARRAY

```
=# SELECT JSON_ARRAY('string', 123, TRUE, ARRAY[1,2,3],
  '{"a": 1}'::jsonb, '[1, {"c": 3}]' FORMAT JSON
);
                          ?column?
-----------------------------------------------------------
 ["string", 123, true, [1,2,3], {"a": 1}, [1, {"c": 3}]]
(1 row)

=# SELECT JSON_ARRAY(SELECT * FROM generate_series(1, 3));
 ?column?
-----------
 [1, 2, 3]
(1 row)
```

SQL/JSON: JSON_ARRAY

NULL ON NULL clause is used for preserving NULL elements which are will be omitted otherwise (ABSENT ON NULL is by default).

```
=# SELECT JSON_ARRAY(1, NULL, 'a');
 ?column?
----------
 [1, "a"]
(1 row)

=# SELECT JSON_ARRAY(1, NULL, 'a' NULL ON NULL);
     ?column?
-----------------
 [1, null, "a"]
(1 row)
```

SQL/JSON: JSON_ARRAYAGG

JSON_ARRAYAGG - aggregates values as JSON[b] array.

Syntax:

```
JSON_ARRAYAGG (
  expression [ FORMAT JSON ]
  [ { NULL | ABSENT } ON NULL ]
  [ RETURNING data_type [ FORMAT JSON ] ]
)
```

SQL/JSON: JSON_ARRAYAGG

All is the same as in JSON_ARRAY except that JSON_ARRAYAGG is transformed into a json[b]_agg() call.

```
=# SELECT JSON_ARRAYAGG(i) FROM generate_series(1, 3) i;
 ?column?
-----------
 [1, 2, 3]
(1 row)
```

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

SQL/JSON examples: JSON_VALUE

```
SELECT x, JSON_VALUE(jsonb '{"a": 1, "b": 2}','$.* ? (@ > $x)' PASSING x AS x
                     RETURNING int
                     DEFAULT -1 ON EMPTY
                     DEFAULT -2 ON ERROR
                    ) y
FROM
generate_series(0, 2) x;
 x | y
---+----
 0 | -2
 1 |  2
 2 | -1
(3 rows)
```

SQL/JSON examples: JSON_QUERY

```
SELECT
        JSON_QUERY(js FORMAT JSONB, '$'),
        JSON_QUERY(js FORMAT JSONB, '$' WITHOUT WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH CONDITIONAL WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH UNCONDITIONAL ARRAY WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH ARRAY WRAPPER)
FROM
        (VALUES
                ('null'),
                ('12.3'),
                ('true'),
                ('"aaa"'),
                ('[1, null, "2"]'),
                ('{"a": 1, "b": [2]}')
        ) foo(js);
```

```
     ?column?      |     ?column?      |     ?column?      |       ?column?       |       ?column?
-------------------+-------------------+-------------------+----------------------+----------------------
 null              | null              | [null]            | [null]               | [null]
 12.3              | 12.3              | [12.3]            | [12.3]               | [12.3]
 true              | true              | [true]            | [true]               | [true]
 "aaa"             | "aaa"             | ["aaa"]           | ["aaa"]              | ["aaa"]
 [1, null, "2"]    | [1, null, "2"]    | [1, null, "2"]    | [[1, null, "2"]]     | [[1, null, "2"]]
 {"a": 1, "b": [2]} | {"a": 1, "b": [2]} | {"a": 1, "b": [2]} | [{"a": 1, "b": [2]}] | [{"a": 1, "b": [2]}]
(6 rows)
```

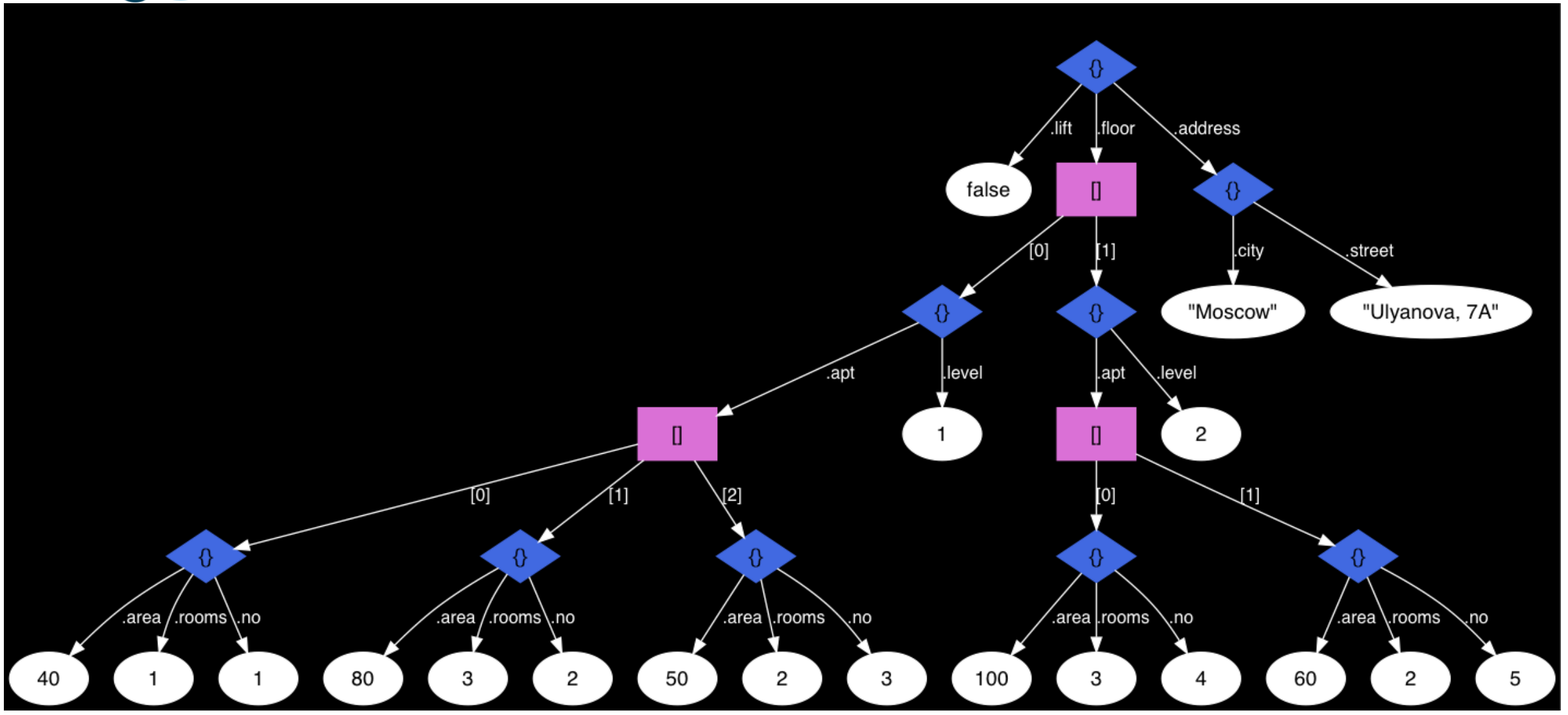
SQL/JSON examples: Constraints

```
CREATE TABLE test_json_constraints (
       js text,
       i int,
       x jsonb DEFAULT JSON_QUERY(jsonb '[1,2]', '$[*]' WITH WRAPPER)
       CONSTRAINT test_json_constraint1
              CHECK (js IS JSON)
       CONSTRAINT test_json_constraint2
CHECK (JSON_EXISTS(js FORMAT JSONB, '$.a' PASSING i + 5 AS int, i::text AS txt))
       CONSTRAINT test_json_constraint3
CHECK (JSON_VALUE(js::jsonb, '$.a' RETURNING int DEFAULT ('12' || i)::int
       ON EMPTY ERROR ON ERROR) > i)
       CONSTRAINT test_json_constraint4
              CHECK (JSON_QUERY(js FORMAT JSONB, '$.a'
WITH CONDITIONAL WRAPPER EMPTY OBJECT ON ERROR) < jsonb '[10]')
);
```

SQL/JSON examples: JSON_TABLE

- Creates a relational view of JSON data.
- Think about UNNEST — creates a row for each object inside JSON array and represent JSON values from within that object as SQL columns values.
- Build on top of XML_TABLE infrastructure (PG 10)

2-floors house



SQL/JSON examples: JSON_TABLE

Floors in relational form. **Returns parts !**

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

SQL/JSON availability

- Github Postgres Professional repository
  https://github.com/postgrespro/sqljson
- WEB-interface to play with SQL/JSON
  http://sqlfiddle.postgrespro.ru/#!21/0/1819
- Technical Report (SQL/JSON) - available for free
  http://standards.iso.org/ittf/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip
- We need your feedback, bug reports and suggestions
- Help us writing documentation !

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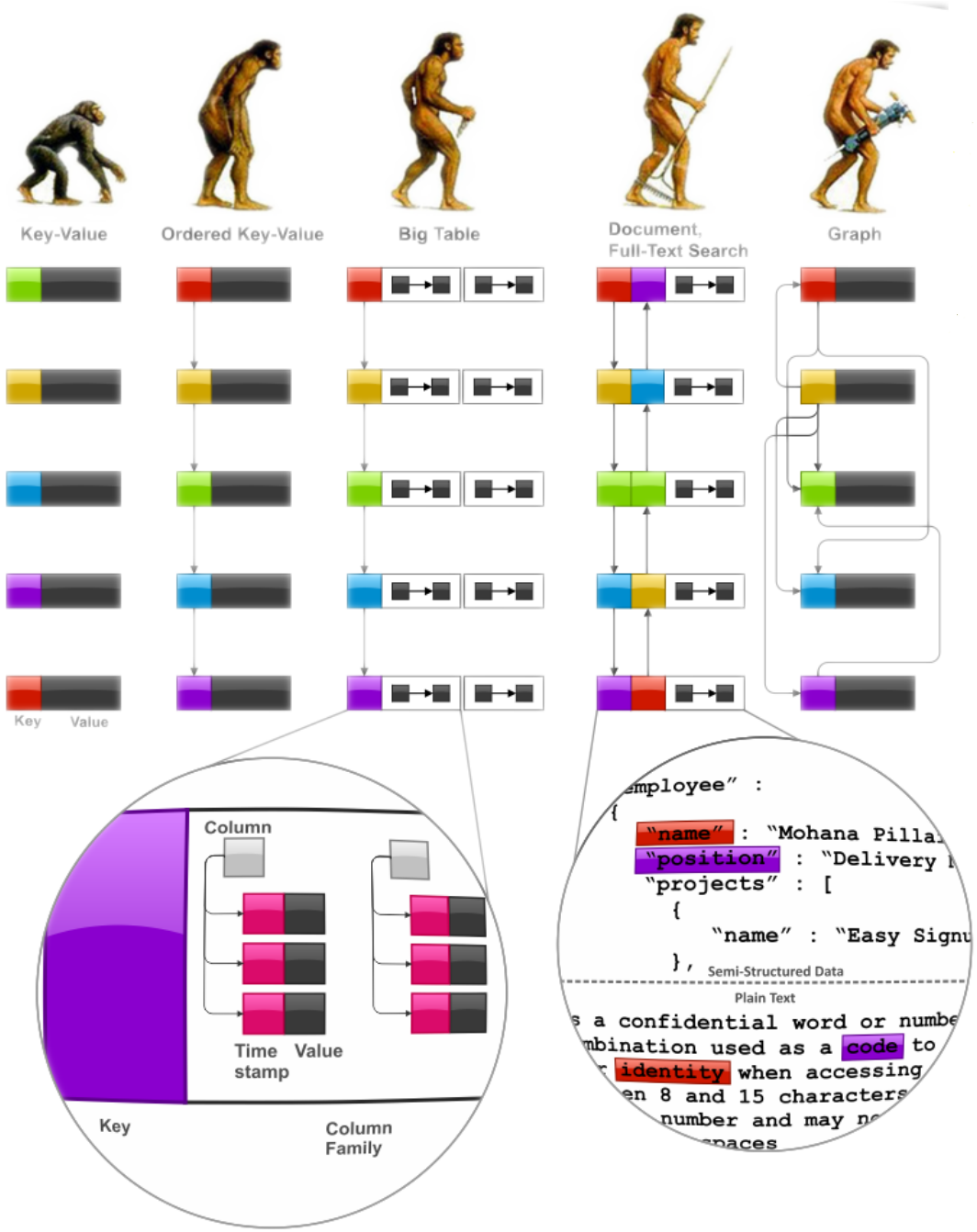

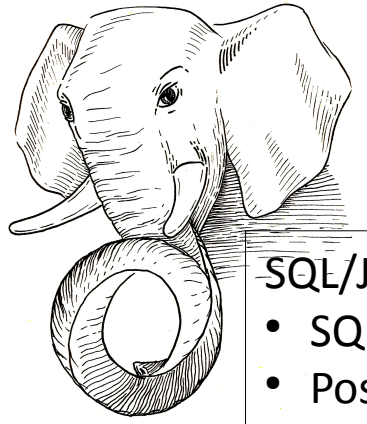

SQL/JSON - 2018
- SQL-2016 standard
- Postgres Pro - 2017

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

JSON - 2012
- Textual storage
- JSON verification

HSTORE - 2003
- Perl-like hash storage
- No nesting
- Indexing

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JSONB COMPRESSION

Transparent compression of jsonb

+ access to the child elements without full decompression

jsonb compression: ideas

- **Keys replaced by their ID in the external dictionary**
- Delta coding for sorted key ID arrays
- Variable-length encoded entries instead of 4-byte fixed-size entries
- Chunked encoding for entry arrays
- Storing integer numerics falling into int32 range as variable-length encoded 4-byte integers

jsonb compression: implementation

- Custom column compression methods:

```
CREATE COMPRESSION METHOD name HANDLER handler_func

CREATE TABLE table_name (
      column_name data_type
      [ COMPRESSED cm_name [ WITH (option 'value' [, ... ]) ] ] ...
)

ALTER TABLE table_name ALTER column_name
      SET COMPRESSED cm_name [ WITH (option 'value' [, ... ]) ]

ALTER TYPE data_type SET COMPRESSED cm_name
```

- attcompression, attcmoptions in pg_catalog.pg_attributes

jsonb compression: jsonbc

- **Jsonbc** - compression method for jsonb type:
  - dictionary compression for object keys
  - more compact variable-length encoding

- All key dictionaries for all jsonbc compressed columns are stored in the pg_catalog.pg_jsonbc_dict (dict oid, id integer, name text)

- Dictionary used by jsonb column is identified by:
  - sequence oid – automatically updated
  - enum type oid – manually updated

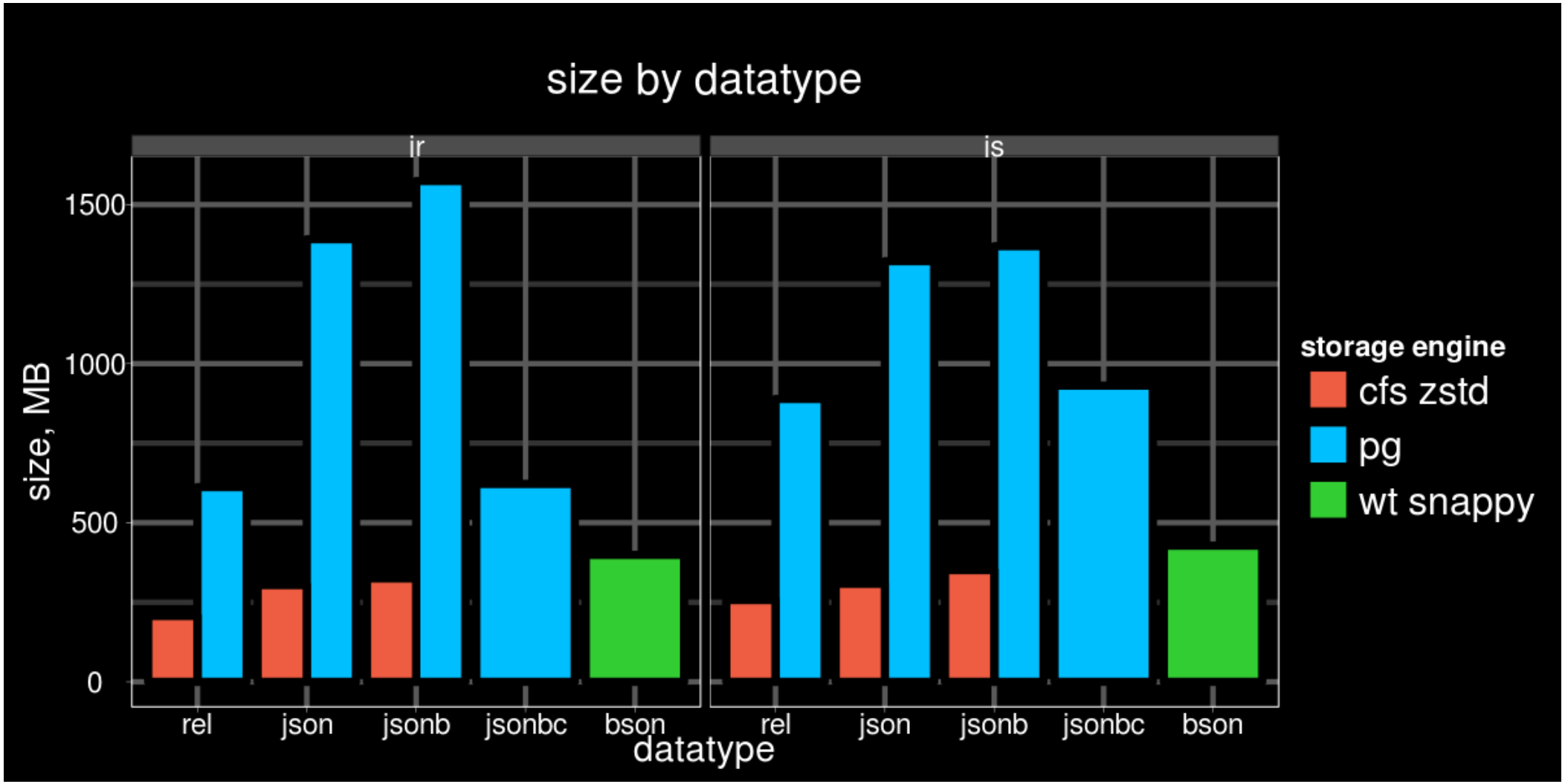
jsonb compression: results

Two datasets:

- js – Delicious bookmarks, 1.2 mln rows (js.dump.gz)
  - Mostly string values
  - Relatively short keys
  - 2 arrays (tags and links) of 3-field objects
- jr – customer reviews data from Amazon, 3mln (jr.dump.gz)
  - Rather long keys
  - A lot of short integer numbers

Also, jsonbc compared with CFS (Compressed File System) – page level compression and encryption in Postgres Pro Enterprise 9.6.

jsonb compression: table size



jsonb compression: summary

- jsonbc can reduce jsonb column size to its relational equivalent size
- jsonbc has a very low CPU overhead over jsonb and sometimes can be even faster than jsonb
- jsonbc compression ratio is significantly lower than in page level compression methods
- Availability:

  https://github.com/postgrespro/postgrespro/tree/jsonbc

  https://commitfest.postgresql.org/15/1294/

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BENCHMARKS:
How NoSQL Postgres is fast

First (non-scientific) benchmark !

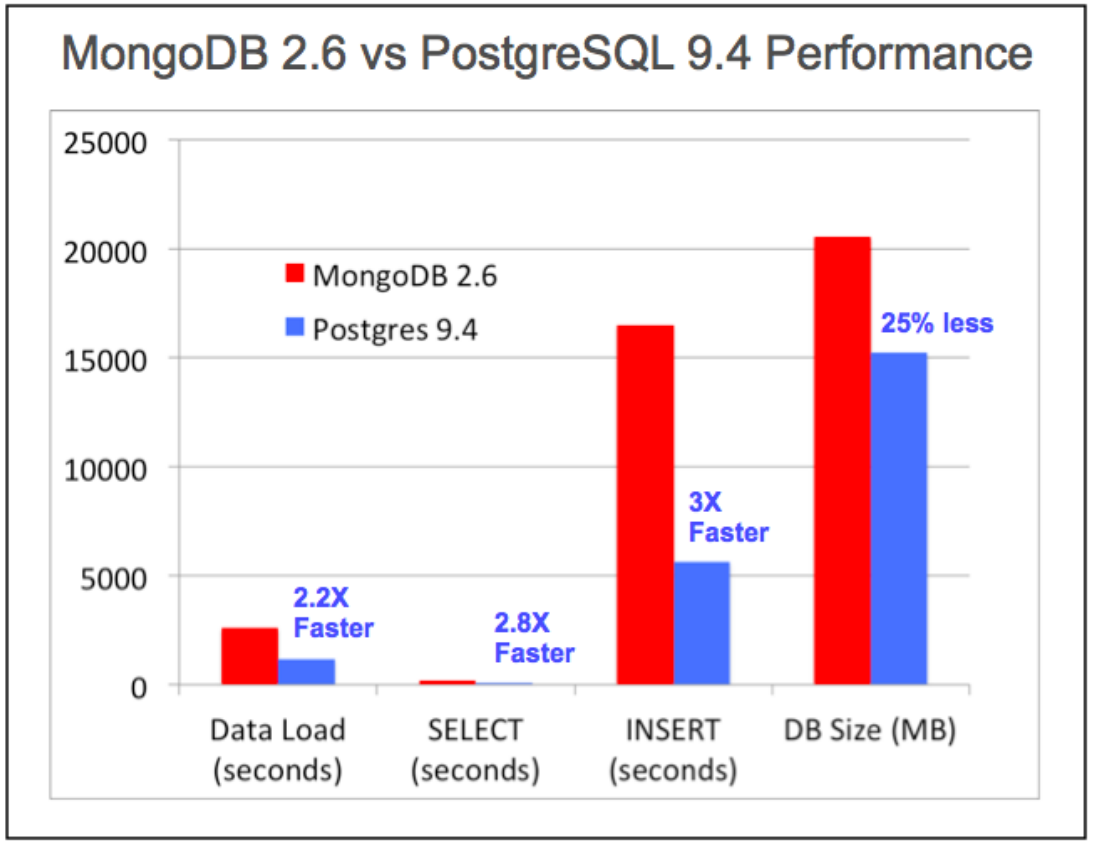
Summary: PostgreSQL 9.4 vs Mongo 2.6.0

- Search key=value (contains @>)
  - json : 10 s seqscan
  - jsonb : 8.5 ms GIN jsonb_ops
  - **jsonb : 0.7 ms GIN jsonb_path_ops**
  - mongo : 1.0 ms btree index
- Index size
  - jsonb_ops - 636 Mb (no compression, 815Mb)
    jsonb_path_ops - 295 Mb
  - jsonb_path_ops (tags) - 44 Mb USING gin((jb->'tags') jsonb_path_ops
  - mongo (tags) - 387 Mb
    mongo (tags.term) - 100 Mb

- Table size
  - postgres : 1.3Gb
  - mongo : 1.8Gb
- Input performance:
  - Text : 34 s
  - Json : 37 s
  - Jsonb : 43 s
  - mongo : 13 m

Engine Yard™

EDB NoSQL Benchmark

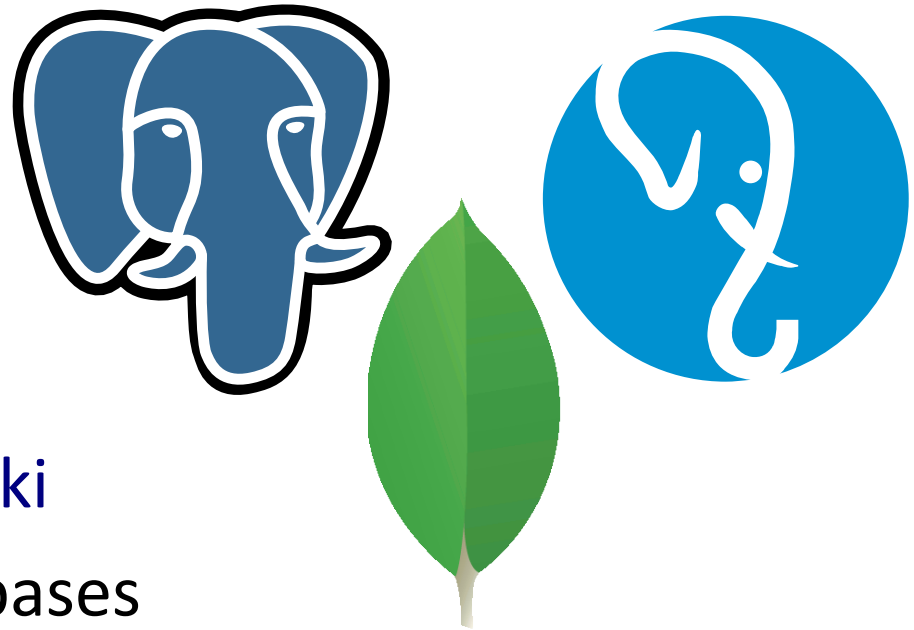


https://github.com/EnterpriseDB/pg_nosql_benchmark

Benchmarking NoSQL Postgres

- Both benchmarks were homemade by postgres people
- People tend to believe independent and «scientific» benchmarks
  - Reproducible
  - More databases
  - Many workloads
  - Open source

YCSB Benchmark



- Yahoo! Cloud Serving Benchmark - https://github.com/brianfrankcooper/YCSB/wiki
- De-facto standard benchmark for NoSQL databases
- Scientific paper «Benchmarking Cloud Serving Systems with YCSB» https://www.cs.duke.edu/courses/fall13/cps296.4/838-CloudPapers/ycsb.pdf
- We run YCBS for Postgres master, MongoDB 3.4.2
  - 1 server with 72 cores, 3 TB RAM, 2 TB SSD for clients
  - 1 server with 72 cores, 3 TB RAM, 2 TB SSD for database
  - 10Gbps switch

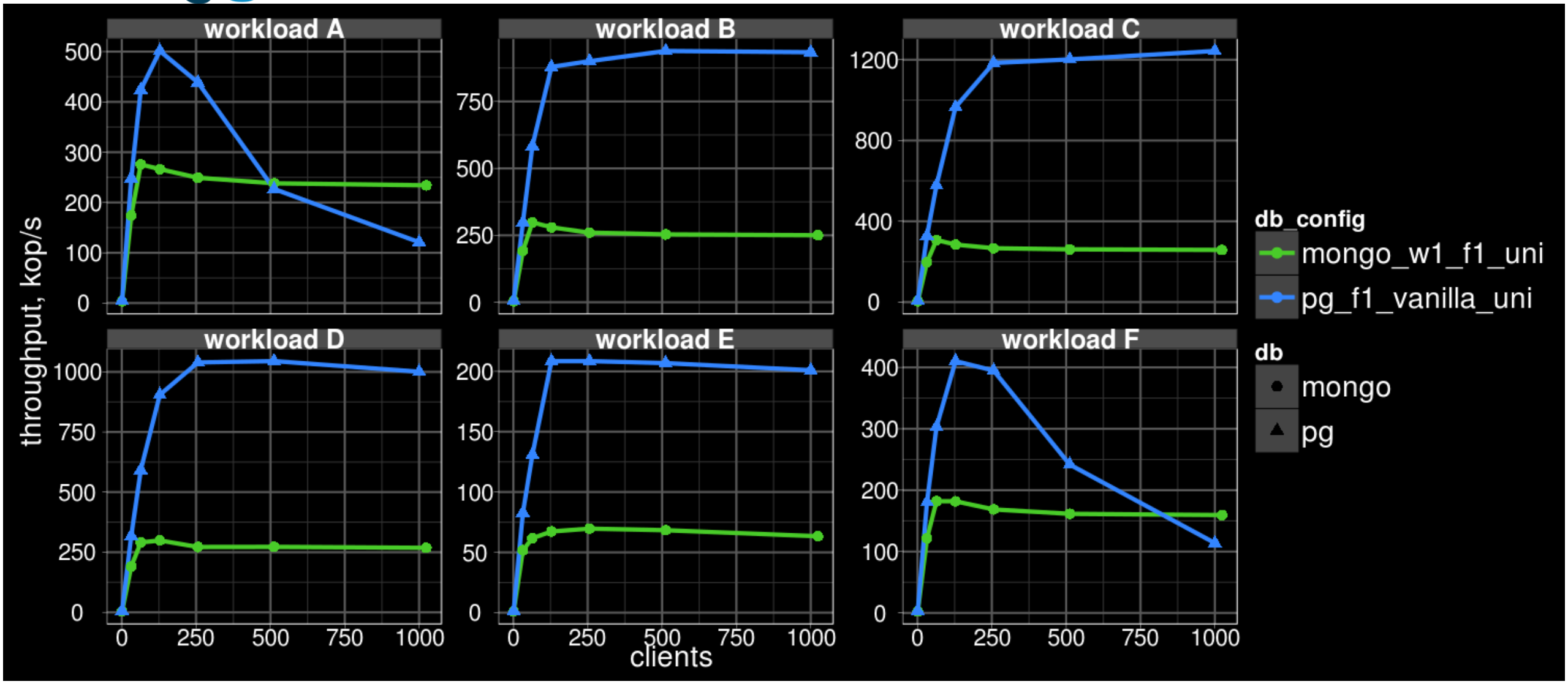
YCSB Benchmark: Core workloads

- Workload A: Update heavy - a mix of 50/50 reads and writes
- Workload B: Read mostly - a 95/5 reads/write mix
- Workload C: Read only — 100% read
- Workload D: Read latest - new records are inserted, and the most recently inserted records are the most popular
- Workload E: Short ranges - short ranges of records are queried
- Workload F: Read-modify-write - the client will read a record, modify it, and write back the changes
- All (except D) workloads uses Zipfian distribution for record selections

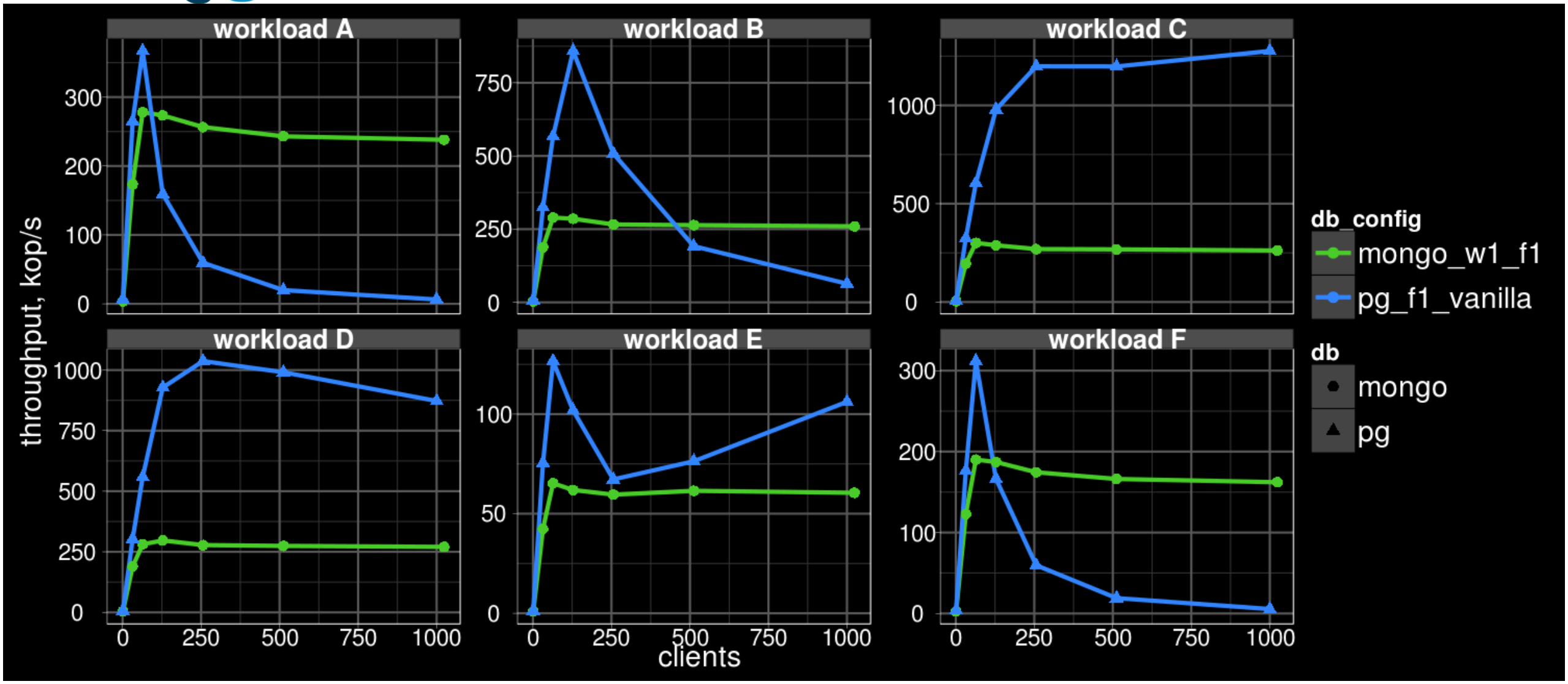
YCSB Benchmark: details (1)

- Postgres 10, synchronous commit=off
  Mongodb 3.4.2 (w1, j0) — 1 mln. rows
- Postgres 10, synchronous commit=on
  Mongodb 3.4.5 (w1, j1)
- We tested:
  - Functional btree index for jsonb, jsonbc, sqljson
  - Mongodb (wiredtiger with snappy compression)
  - Return a whole json, just one field, small range

Uniform distribution of queries



Zipf distributions of queries



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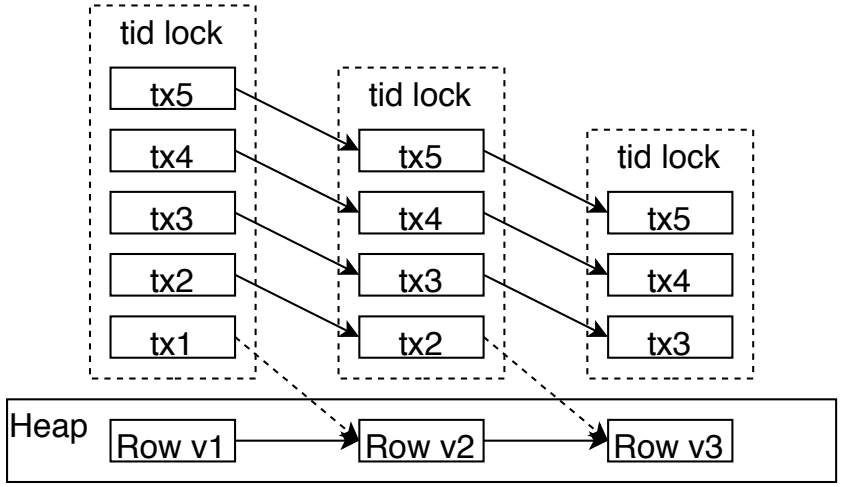
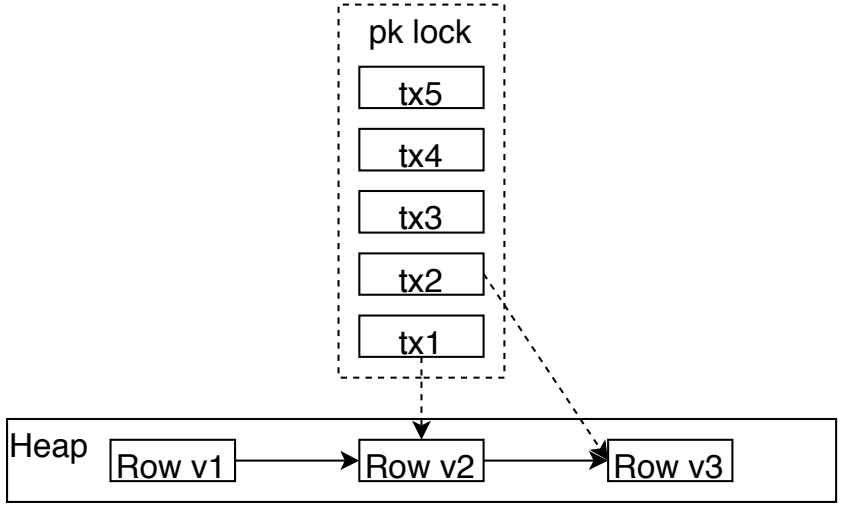
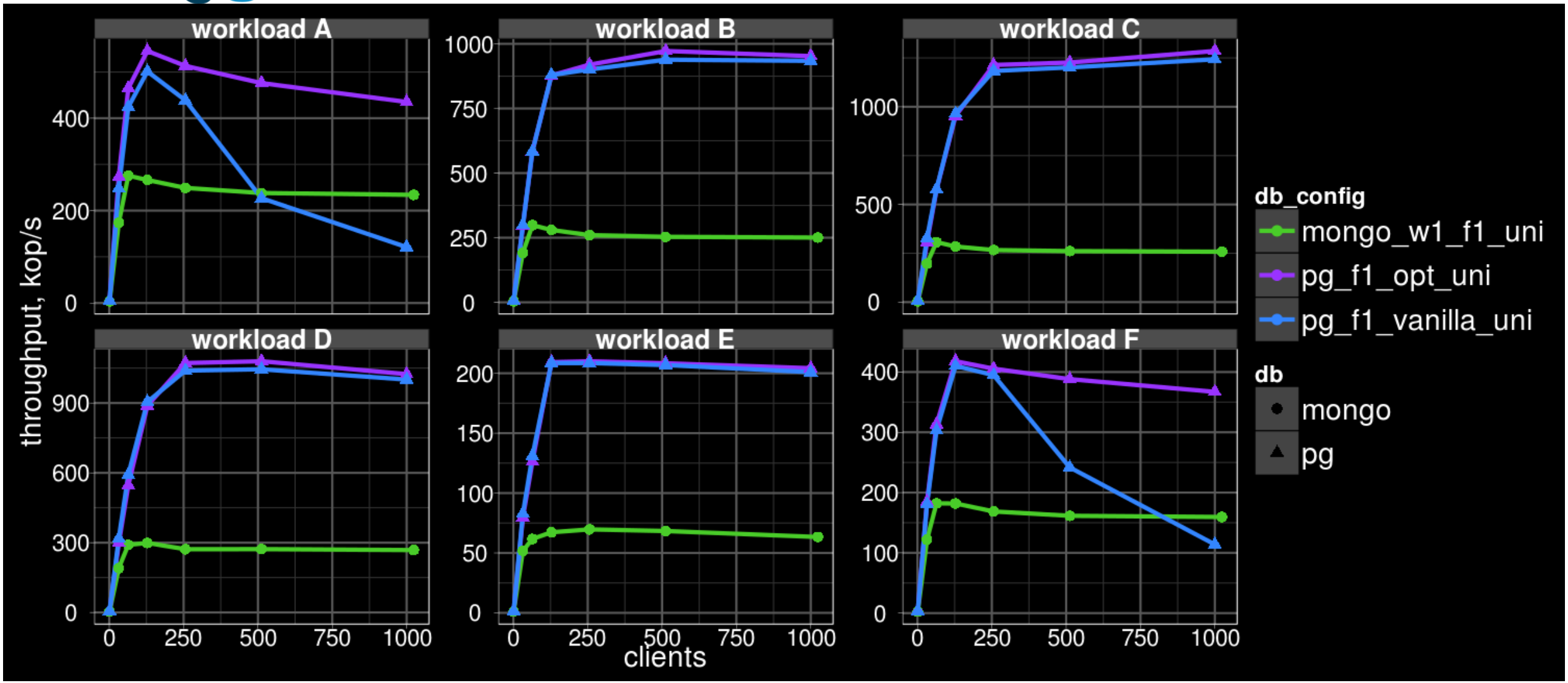
Optimization of high-contention write



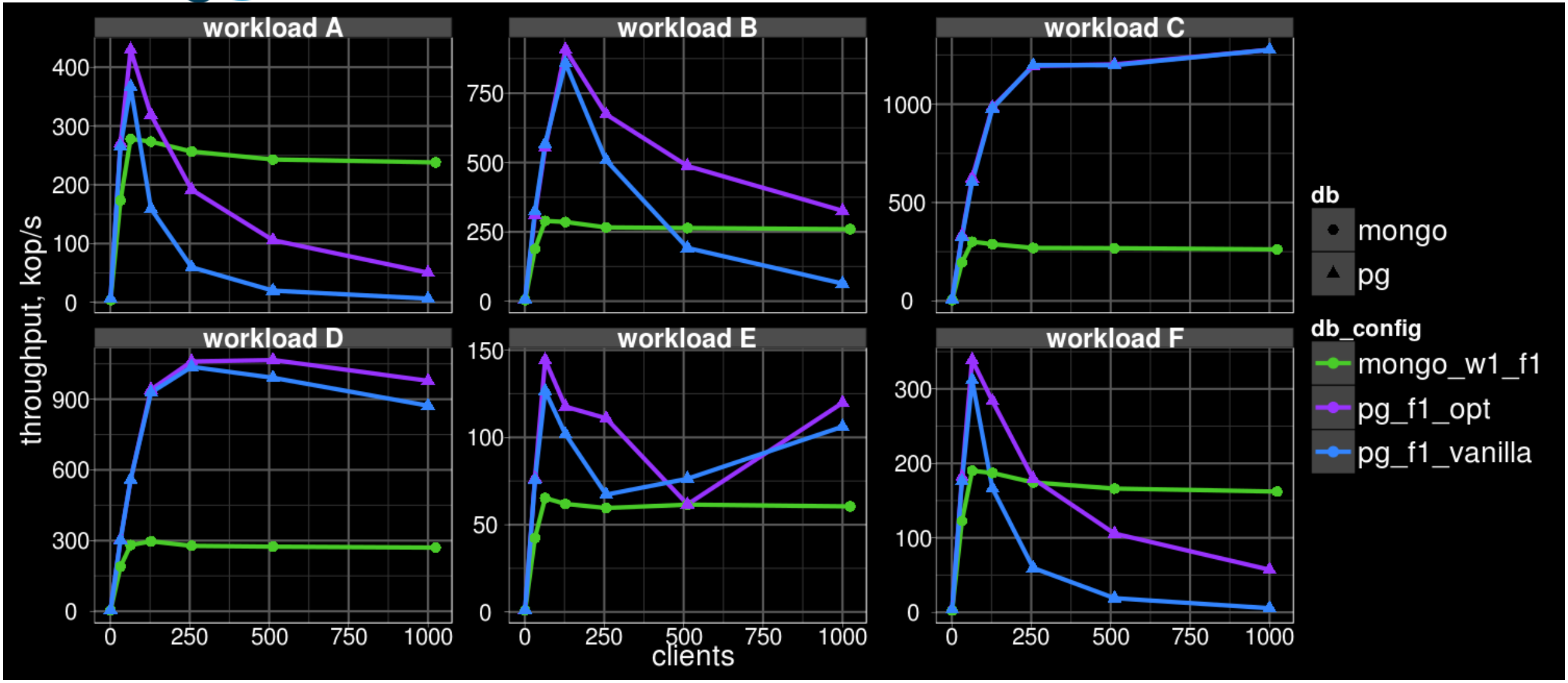


- Tid (physical location of tuple) lock operations are expensive
  - Each operation requires lookup in hash table in shared memory
  - For n backends - n^2 operations !
- Use primary key to lock tuple until end of transaction

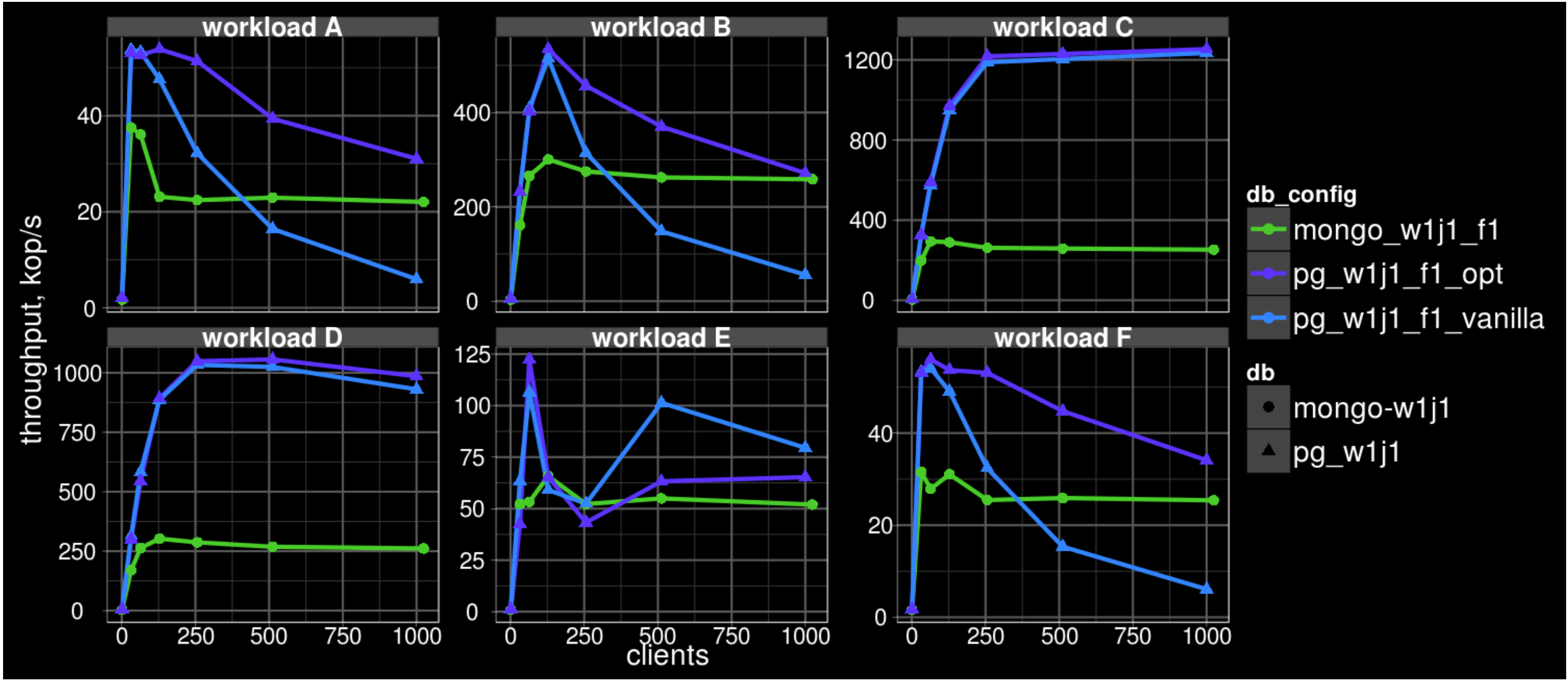
Uni with postgres optimized — **GOOD !**



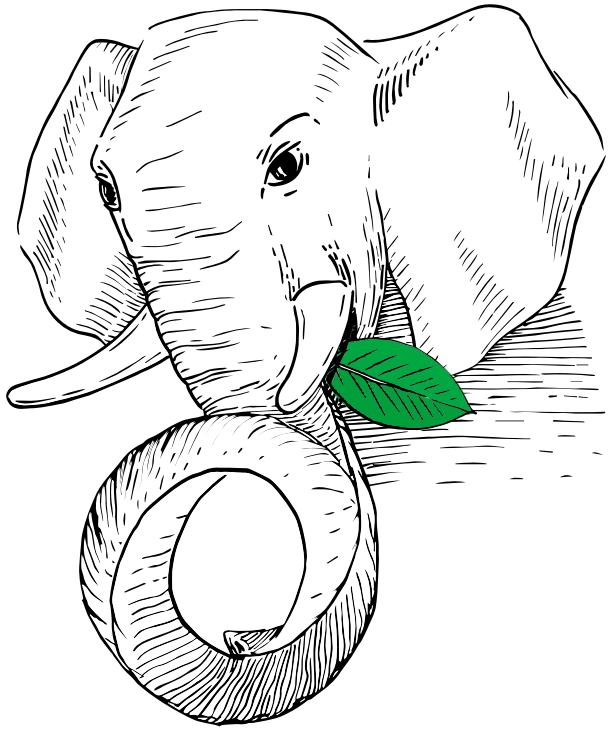
Zipf with postgres optimized — **So-So :(**



Persistent case (sync. Commit) — Good :)



Conclusion



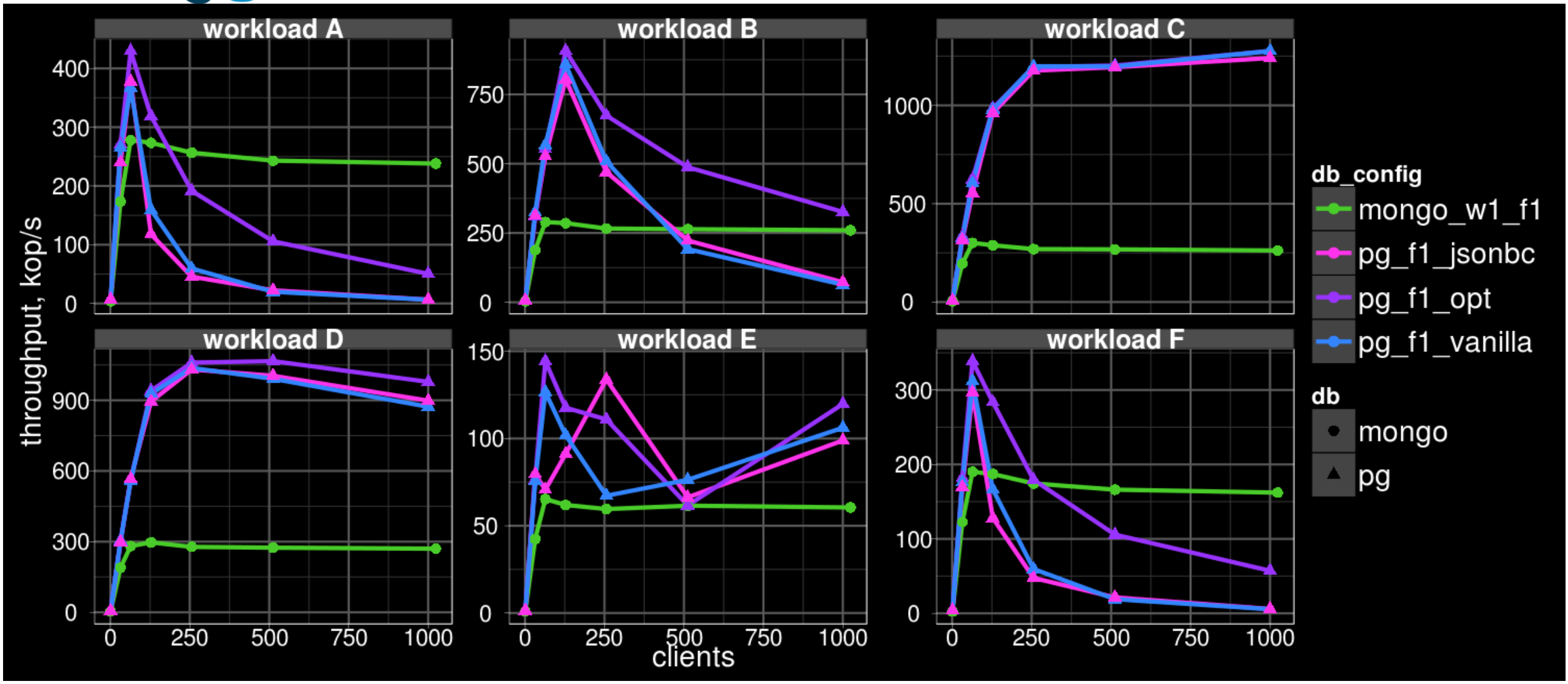
- For uniform queries
  «Postgres optimized» > Mongodb !

- For Zipfian queries Postgres quickly degrades for workloads A,B (high contention writes)

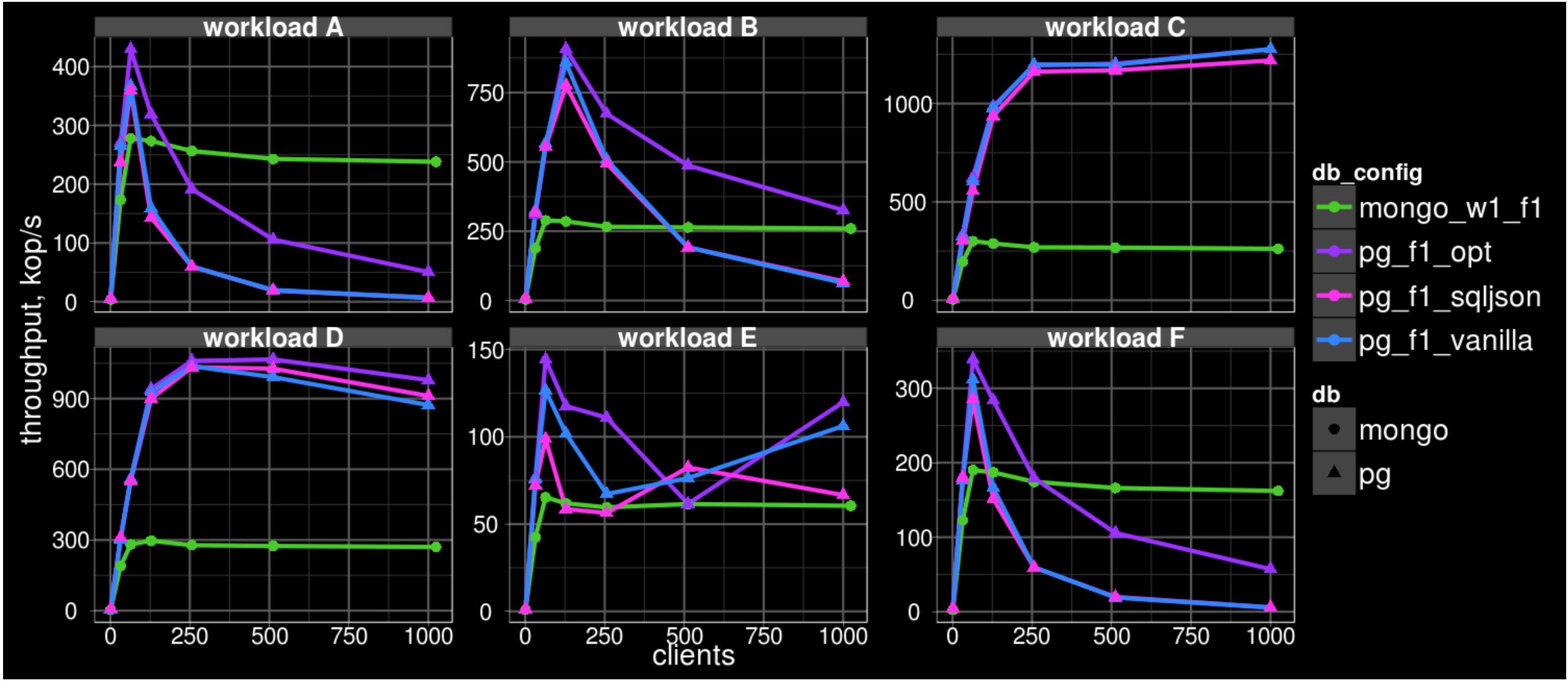
  Use max_connections < 250 and be happy !

- Persistent NoSQL is good case for Postgres.
  max_connections up to 1000

Jsonbc — no overhead !



SQL/JSON — the same as JSONB



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JSONB subscripting syntax

- Based on «Generic type subscripting» on commitfest https://commitfest.postgresql.org/15/1062/
  Extends array syntax to support other types

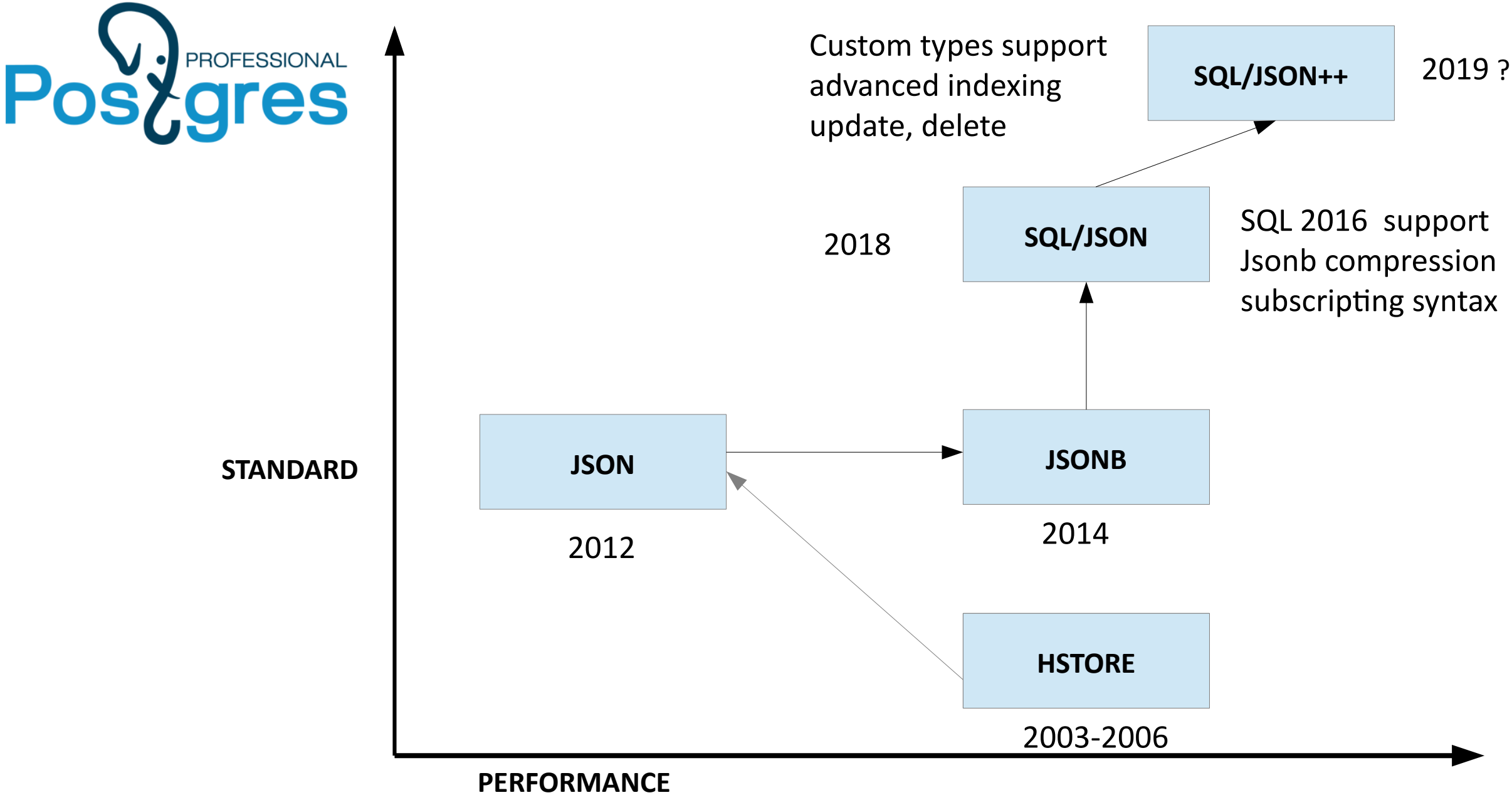
```
UPDATE test_table set ARR[1] = 100;

SELECT JS['a']['a1']['a2'] FROM test_table;

UPDATE test_table SET JS['a']['b'] = '2'::jsonb;
```

Summary

- Postgres is already a good NoSQL database + clear roadmap
- Move from NoSQL to Postgres to avoid nightmare !
- SQL/JSON provides better flexibility and interoperability
  - Expect it in Postgres 11 (Postgres Pro 10)
  - Need community help (testing, documentation)
- JSONB dictionary compression (jsonbc) is really useful
  - Expect it in Postgres 11 (Postgres Pro 10)
- Postgres can be faster Mongodb for uniform data
- Postgres can be faster Mongodb for zipfian distribution and low concurrency (#clients < 200) and degrades for high-contention write (#clients > 200), this needs to be fixed !


Custom types support
advanced indexing
update, delete
SQL/JSON++
2019 ?
2018
SQL/JSON
SQL 2016 support
Jsonb compression
subscripting syntax
JSON
JSONB
2012
2014
HSTORE
2003-2006
STANDARD
PERFORMANCE

PEOPLE BEHIND JSON[B]

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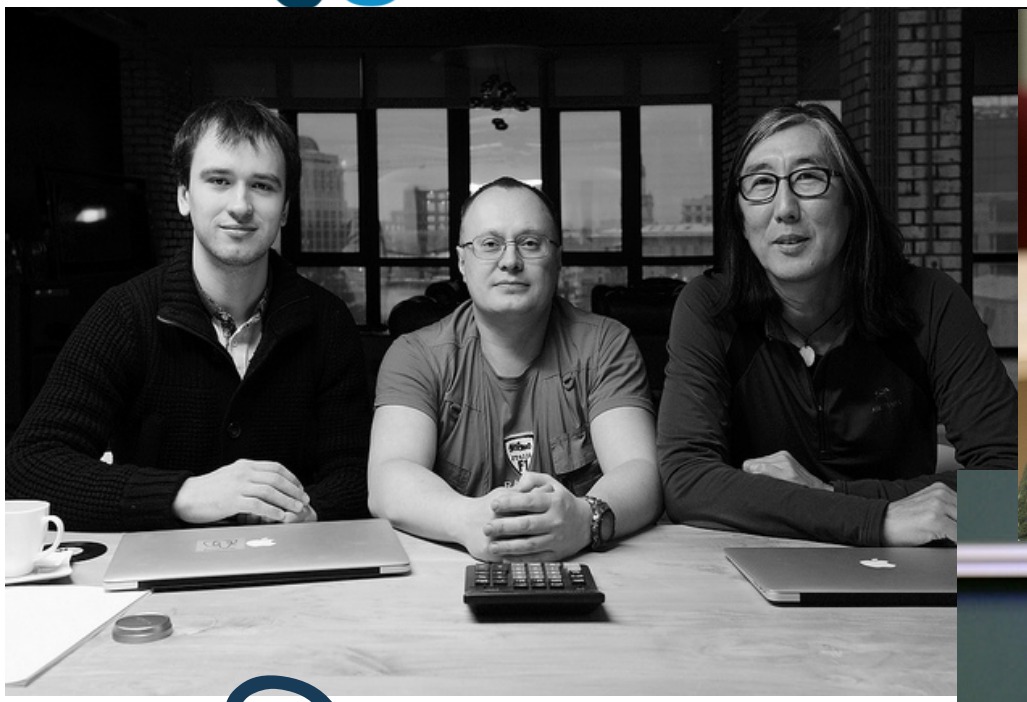

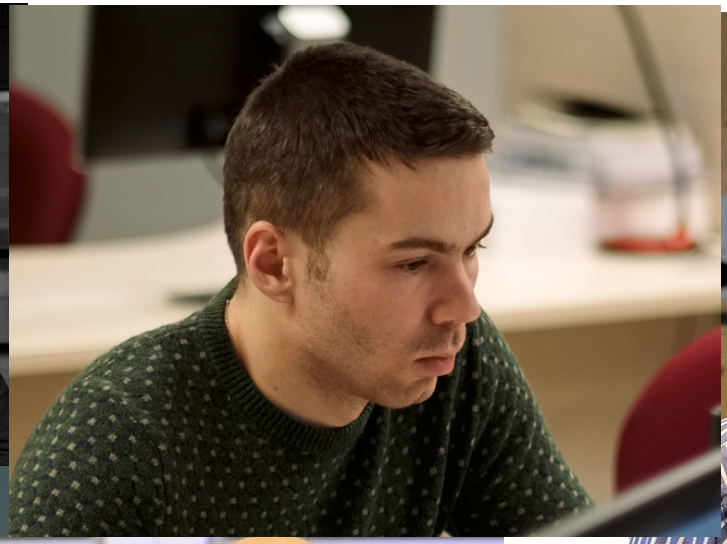

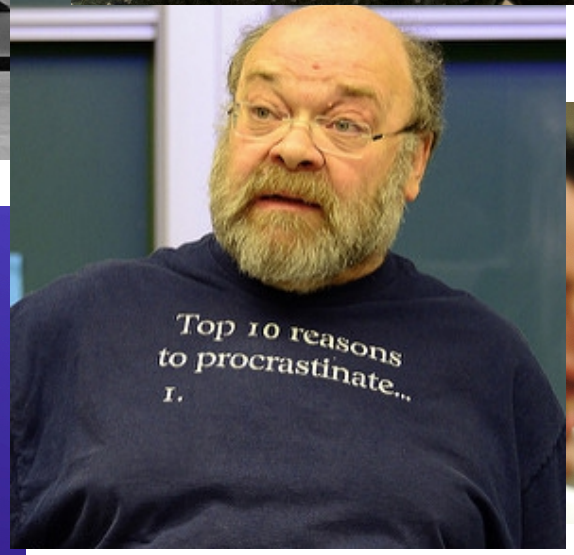

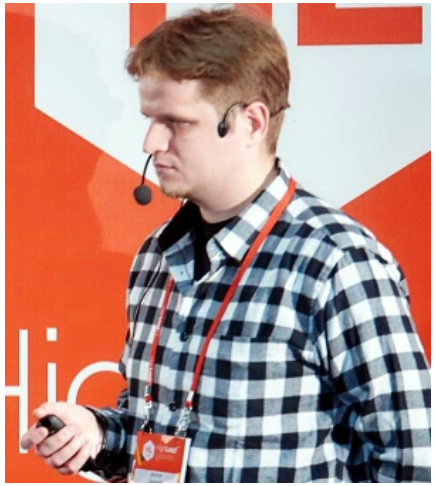

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HEROKU

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Dziękuje za uwagę !