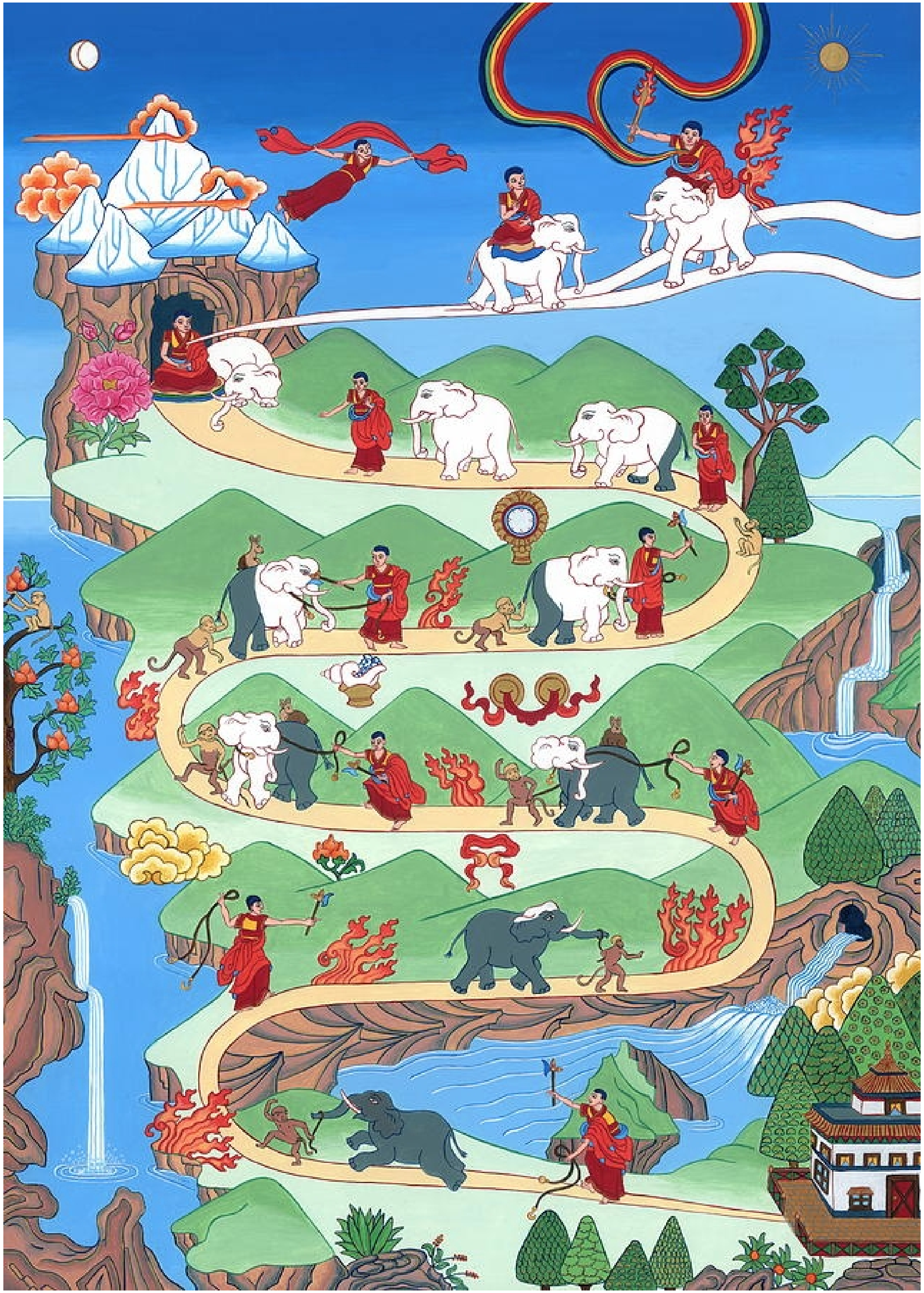

Do you need a Full-Text Search in PostgreSQL ?

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Oleg Bartunov, major PostgreSQL contributor since Postgres95

PROFESSIONAL Postgres

What is a Full Text Search ?

- Full text search
  - Find documents, which match a query
  - Sort them in some order (optionally)
- Typical Search
  - Find documents with **all words** from the query
  - Return them sorted by relevance

What is a document ?

- Arbitrary text attribute
- Combination of text attributes from the same or different tables (result of join)

```
msg (id, lid, subject, body);
lists (lid, list);

SELECT l.list || m.subject || m.body_plain as doc


Don’t forget about COALESCE (text,’’)
```

What is a query ?

- Arbitrary text

  ‘open source’
- Text with some query language

```
'postgresql "open source * database" -die +most'
```

Why FTS in PostgreSQL ?

- Feed database content to external search engines
  - They are fast !

  BUT
- They can't index all documents - could be totally virtual
- They don't have access to attributes - no complex queries
- They have to be maintained — headache for DBA
- Sometimes they need to be certified
- They don't provide instant search (need time to download new data and reindex)
- They don't provide consistency — search results can be already deleted from database

Your system may looks like this

FTS in PostgreSQL

- **FTS requirements**
  - **Full integration with database engine**
    - Transactions
    - Concurrent access
    - Recovery
    - Online index
  - Configurability (parser, dictionary...)
  - Scalability

Text Search Operators

- Traditional text search operators
  (TEXT op TEXT, op - ~, ~*, LIKE, ILIKE)

```
=# select title  from apod where title ~* 'x-ray' limit 5;
                 title
----------------------------------------
 The X-Ray Moon
 Vela Supernova Remnant in X-ray
 Tycho's Supernova Remnant in X-ray
 ASCA X-Ray Observatory
 Unexpected X-rays from Comet Hyakutake
(5 rows)

=# select title  from apod where title ilike '%x-ray%' limit 5;
                title
----------------------------------------
 The Crab Nebula in X-Rays
 X-Ray Jet From Centaurus A
 The X-Ray Moon
 Vela Supernova Remnant in X-ray
 Tycho's Supernova Remnant in X-ray
(5 rows)
```

Text Search Operators

- Traditional text search operators
  (TEXT op TEXT, op - ~, ~*, LIKE, ILIKE)
  - No linguistic support
    - What is a word ?
    - What to index ?
    - Word «normalization» ?
    - Stop-words (noise-words)
  - No ranking - all documents are equally similar to query
  - Slow, documents should be seq. scanned
    9.3+ index support of ~* (pg_trgm)

select * from man lines where man line ~* '(?:(?:p(?:ostgres(?:ql)?|g?sql)|sql)) (?:(?:(?:mak|us)e|do|is))';

`One of (postgresql,sql,postgres,pgsql,psql) space One of (do,is,use,make)`

FTS in PostgreSQL

- OpenFTS — 2000, Pg as a storage
- GiST index — 2000, thanks Rambler
- Tsearch — 2001, contrib:no ranking
- Tsearch2 — 2003, contrib:config
- GIN —2006, thanks, JFG Networks
- FTS — 2006, in-core, thanks,EnterpriseDB
- RUM –- 2016, extension, Postgres Pro

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FTS data types and operators

- **tsvector** – data type for document optimized for search
  - Sorted array of lexems
  - Positional information
  - Structural information (importance)
- **tsquery** – textual data type for query with boolean operators & | ! ()

- **Full text search operator:** tsvector @@ tsquery

```
=# SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector
                        @@
                  'cat & rat':: tsquery;
```

FTS configuration

1) Parser breaks text on to (token, type) pairs
2) Tokens converted to the lexems using dictionaries specific for token type

- Extendability:
  - Pluggable parser and dictionaries
  - FTS configuration defines parser and dictionaries
  - FTS configurations used for document and query processing
- \dF{,p,d}[+] [pattern] — psql FTS
- SQL interface:

```
{CREATE | ALTER | DROP} TEXT SEARCH {CONFIGURATION | DICTIONARY | PARSER}
```

FTS in PostgreSQL

- Document to tsvector:
  - to_tsvector([cfg], text|json|jsonb)
    cfg — FTS configuration,
    GUC default_text_search_config

```
select to_tsvector('It is a very long story about true and false');
              to_tsvector
----------------------------------------
 'fals':10 'long':5 'stori':6 'true':8
(1 row)

select to_tsvector('simple', 'It is a very long story about true and false');
                                   to_tsvector
-----------------------------------------------------------------------------------------
 'a':3 'about':7 'and':9 'false':10 'is':2 'it':1 'long':5 'story':6 'true':8 'very':4
(1 row)
```

FTS in PostgreSQL

- JSON[b] to tsvector:
  - Notice, results are different for json and jsonb !
    Jsonb: keys are sorted, Json: spaces are preserved
  - Phrases are preserved

```
select to_tsvector(jb) from (values ('
{
    "abstract": "It is a very long story about true and false",
    "title": "Peace and War",
    "publisher": "Moscow International house"
 }
'::json[b])) foo(jb) as tsvector_json[b]
                                   tsvector_json
------------------------------------------------------------------------------------------
 'fals':10 'hous':18 'intern':17 'long':5 'moscow':16 'peac':12 'stori':6 'true':8 'war':14
(1 row)

                                   tsvector_jsonb
------------------------------------------------------------------------------------------
 'fals':14 'hous':18 'intern':17 'long':9 'moscow':16 'peac':1 'stori':10 'true':12 'war':3
(1 row)
```

Tsvector editing functions

- Different parts of document can be marked to use for ranking at search time.
  setweight(tsvector, «char», text[] - add label to lexemes from text[]

```
select setweight( to_tsvector('english', '20-th anniversary of PostgreSQL'),
'A',  '{postgresql,20}');
                   setweight
------------------------------------------------
 '20':1A 'anniversari':3 'postgresql':5A 'th':2
(1 row)
```

- ts_delete(tsvector, text[]) - delete lexemes from tsvector

```
select ts_delete( to_tsvector('english', '20-th anniversary of PostgreSQL'),
'{20,postgresql}'::text[]);
       ts_delete
------------------------
 'anniversari':3 'th':2
(1 row)
```

Tsvector editing functions

- unnest(tsvector)

```
select * from unnest( setweight( to_tsvector('english',
'20-th anniversary of PostgreSQL'),'A',  '{postgresql,20}'));
   lexeme    | positions | weights
-------------+-----------+---------
 20          | {1}       | {A}
 anniversari | {3}       | {D}
 postgresql  | {5}       | {A}
 th          | {2}       | {D}
(4 rows)
```

- tsvector_to_array(tsvector) — tsvector to text[]
  array_to_tsvector(text[])

```
select tsvector_to_array( to_tsvector('english',
'20-th anniversary of PostgreSQL'));
       tsvector_to_array
--------------------------------
 {20,anniversari,postgresql,th}
(1 row)
```

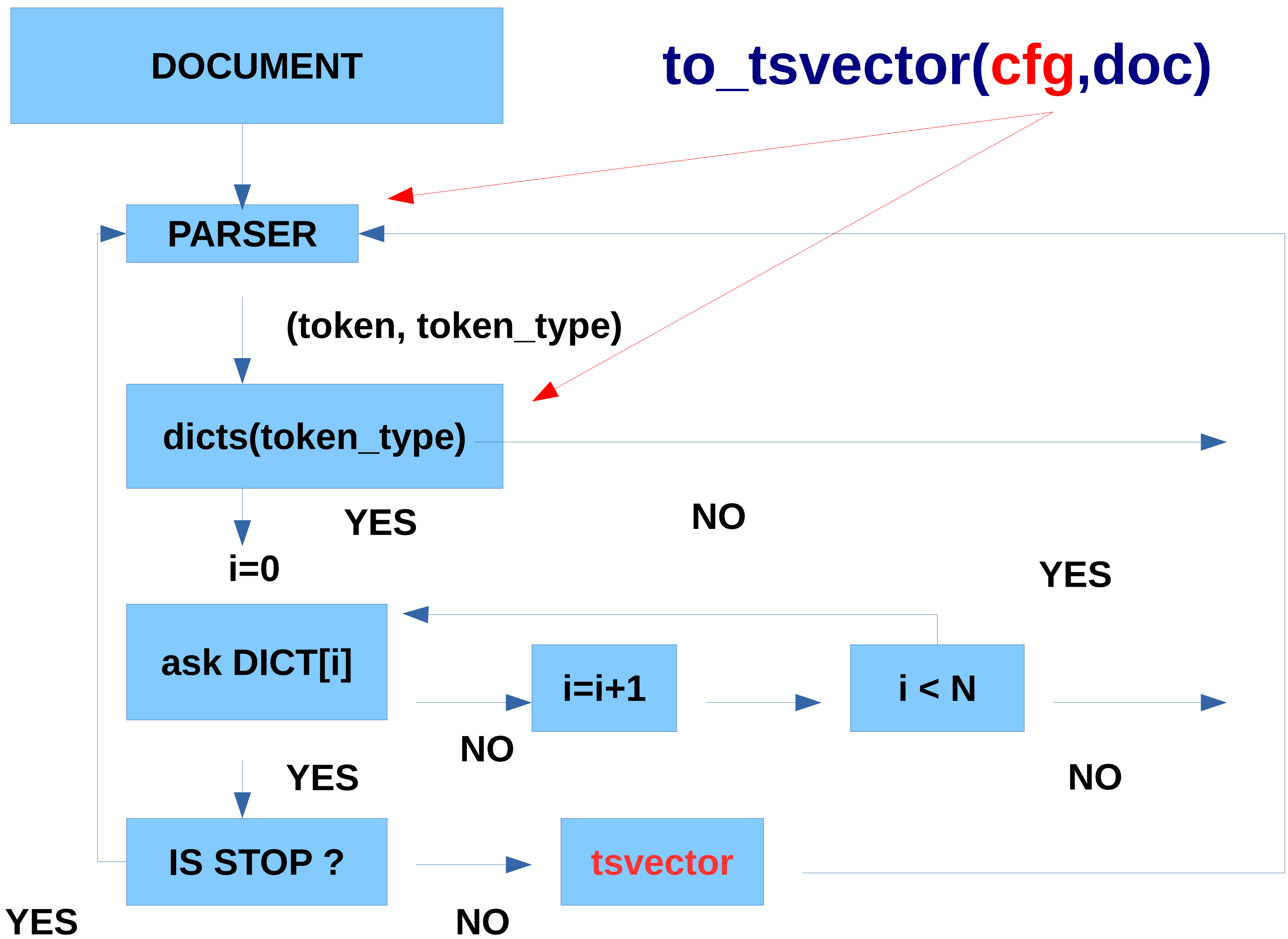
Tsvector editing functions

- ts_filter(tsvector,text[]) - fetch lexemes with specific label{s}

```
select ts_filter($$'20':2A 'anniversari':4C 'postgresql':1A,6A 'th':3$$::tsvector,
'{C}');
    ts_filter
------------------
 'anniversari':4C
(1 row)

select ts_filter($$'20':2A 'anniversari':4C 'postgresql':1A,6A 'th':3$$::tsvector,
'{C,A}');
                  ts_filter
---------------------------------------------
 '20':2A 'anniversari':4C 'postgresql':1A,6A
(1 row)
```

FTS PostgreSQL



FTS in PostgreSQL

- Parser breaks document into tokens

parser

```
=# select * from ts_token_type('default');
 tokid |      alias      |               description
-------+-----------------+------------------------------------------
     1 | asciiword       | Word, all ASCII
     2 | word            | Word, all letters
     3 | numword         | Word, letters and digits
     4 | email           | Email address
     5 | url             | URL
     6 | host            | Host
     7 | sfloat          | Scientific notation
     8 | version         | Version number
     9 | hword_numpart   | Hyphenated word part, letters and digits
    10 | hword_part      | Hyphenated word part, all letters
    11 | hword_asciipart | Hyphenated word part, all ASCII
    12 | blank           | Space symbols
    13 | tag             | XML tag
    14 | protocol        | Protocol head
    15 | numhword        | Hyphenated word, letters and digits
    16 | asciihword      | Hyphenated word, all ASCII
    17 | hword           | Hyphenated word, all letters
    18 | url_path        | URL path
    19 | file            | File or path name
    20 | float           | Decimal notation
    21 | int             | Signed integer
    22 | uint            | Unsigned integer
    23 | entity          | XML entity
(23 rows)
```

Dictionaries

- **Dictionary** – is a **program**, which accepts token on input and returns an array of lexems, NULL if token doesn‘t recognized and empty array for stop-word.
- ts_lexize(dictionary)

```
SELECT ts_lexize('english_hunspell','a') as stop,
ts_lexize('english_hunspell','elephants') AS elephants,
ts_lexize('english_hunspell','elephantus') AS unknown;
 stop |  elephants  | unknown
------+-------------+---------
 {}   | {elephant}  | (null)
(1 row)
```

- Dictionary API allows to develop any custom dictionaries
  - Truncate too long numbers
  - Convert colors
  - Convert URLs to canonical way

    http://a.in/a/./index.html → http://a.in/a/index.html

Dictionaries

- Dictionary — is a program !

```
=# select ts_lexize('intdict', 11234567890);
  ts_lexize
----------
 {112345}
=# select ts_lexize('roman', 'XIX');
 ts_lexize
-------------
 {19}

=# select ts_lexize('colours','#FFFFFF');
ts_lexize
------------
{white}
```

Astronomical dictionary

Dictionary with regexp support (pcre library)

```
# Messier objects
(M|Messier)(\s|-)?((\d){1,3}) M$3
# catalogs
(NGC|Abell|MKN|IC|H[DHR]|UGC|SAO|MWC)(\s|-)?((\d){1,6}[ABC]?) $1$3
(PSR|PKS)(\s|-)?([JB]?)(\d\d\d\d)\s?([+-]\d\d)\d? $1$4$5
# Surveys
OGLE(\s|-)?((I){1,3}) ogle
2MASS twomass
# Spectral lines
H(\s|-)?(alpha|beta|gamma) h$2
(Fe|Mg|Si|He|Ni)(\s|-)?((\d)|([IXV])+) $1$3
# GRBs
gamma\s?ray\s?burst(s?) GRB
GRB\s?(\d\d\d\d\d\d)([abcd]?) GRB$1$2
```

```
SELECT ts_lexize('regex', 'ngc 1234');
 ts_lexize
-----------
 {ngc1234}
(1 row)
```

Built-in Dictionaries

Dictionary templates:

1. Simple
   - convert the input token to lower case
   - exclude stop words
2. Synonym (also, contrib/xsyn)
   - replace word with a synonym

   Example of .syn file:

```
postgres    pgsql
postgresql pgsql
postgre     pgsql
```

Built-in Dictionaries

3. Thesaurus

   - replace phrase by indexed phrase

   Example of .ths file:

```
booking tickets : order invitation cards
booking ? tickets : order invitation Cards
```

4. Snowball stemmer

   - reduce words by stemming algorithms
   - recognizes everything
   - exclude stop words

```
SELECT ts_lexize('portuguese_stem','responsáveis');
 ts_lexize
-----------
 {respons}
(1 row)
```

Built-in Dictionaries

- Portuguese snowball stemmer dictionary

```
 viva  | vivo  | viver
-------+-------+-------
 {viv} | {viv} | {viv}


select ts_lexize('portuguese_stem','responsáveis');
 ts_lexize
-----------
 {respons}
(1 row)
```

- Available as a part of PostgreSQL core

Built-in Dictionaries

5. Ispell

- normalize different linguistic forms of a word into the same lexeme. Try to reduce an input word to its infinitive form
- support dictionary file formats: Ispell, MySpell, Hunspell
- exclude stop words

```
        viva          |     vivo       |  viver
----------------------+----------------+---------
 {viva,vivo,viver} | {vivo,viver} | {viver}
```

Filter dictionary – unaccent

contrib/unaccent - unaccent text search dictionary and function to remove accents (suffix tree, ~ 25x faster *translate*() solution)

```
1. Unaccent dictionary does nothing and returns NULL.
(lexeme 'Hotels' will be passed to the next dictionary if any)

=# select ts_lexize('unaccent','Hotels') is NULL;
 ?column?
----------
 t

2. Unaccent dictionary removes accent and returns 'Hotel'.
(lexeme 'Hotel' will be passed to the next dictionary if any)

=# select ts_lexize('unaccent','Hôtel');
 ts_lexize
----------
 {Hotel}
```

Filter dictionary - unaccent

```
CREATE TEXT SEARCH CONFIGURATION fr ( COPY = french );
ALTER TEXT SEARCH CONFIGURATION fr ALTER MAPPING FOR hword, hword_part, word
    WITH unaccent, french_stem;
```

```
=# select to_tsvector('fr','Hôtel de la Mer') @@ to_tsquery('fr','Hotels');
 ?column?
----------
 t
```

```
=# select ts_headline('fr','Hôtel de la Mer',to_tsquery('fr','Hotels'));
      ts_headline
------------------------
  <b>Hôtel</b> de la Mer
```

FTS in PostgreSQL

- Each token processed by a set of dictionaries

```
=# \dF+ russian
Text search configuration "pg_catalog.russian"
Parser: "pg_catalog.default"
      Token      | Dictionaries
-----------------+--------------
 asciihword      | english_stem
 asciiword       | english_stem
 email           | simple
 file            | simple
 float           | simple
 host            | simple
 hword           | russian_stem
 hword_asciipart | english_stem
 hword_numpart   | simple
 hword_part      | russian_stem
 int             | simple
 numhword        | simple
 numword         | simple
 sfloat          | simple
 uint            | simple
 url             | simple
 url_path        | simple
 version         | simple
 word            | russian_stem
```

```
ts_lexize('english_stem','stars')
-----------------------------------------
        star
```

FTS in PostgreSQL

- Token processed by dictionaries until it recognized
- It is discarded, if it's not recognized

Rule: from «specific» dictionary to a «common» dictionary

```
=# \dF+ pg
                  Configuration "public.pg"
Parser name: "pg_catalog.default"
Locale: 'ru_RU.UTF-8' (default)
    Token     |                  Dictionaries
--------------+-------------------------------------------------------
 file         | pg_catalog.simple
 host         | pg_catalog.simple
 hword        | pg_catalog.simple
 int          | pg_catalog.simple
 lhword       | public.pg_dict,public.en_ispell,pg_catalog.en_stem
 lpart_hword  | public.pg_dict,public.en_ispell,pg_catalog.en_stem
 Lword        | public.pg_dict,public.en_ispell,pg_catalog.en_stem
 nlhword      | pg_catalog.simple
 nlpart_hword | pg_catalog.simple
```

lowercase

Stemmer recognizes everything

FTS in PostgreSQL

What is the benefit ?

Document processed only once when inserting to table, no overhead in search

- Document parsed into tokens using pluggable parser
- Tokens converted to lexems using pluggable dictionaries
- Words positions and importance are stored and used for ranking
- Stop-words ignored

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Query processing

- Query to tsquery:
  - to_tsquery([cfg], text)
    .
    Better, always specify *cfg* (immutable vs stable) !

```
select to_tsquery('supernovae & stars');
      to_tsquery
----------------------
 'supernova' & 'star'
(1 row)
```

  - plainto_tsquery([cfg],text) – words are AND-ed

```
select plainto_tsquery('supernovae  stars');
   plainto_tsquery
----------------------
 'supernova' & 'star'
(1 row)
```

Query processing

- Queries 'A & B'::tsquery and 'B & A'::tsquery are equivalent

```
select 'a:1 b:2'::tsvector @@ 'a & b'::tsquery,
       'a:1 b:2'::tsvector @@ 'b & a'::tsquery;
 ?column? | ?column?
----------+----------
 t        | t
```

- Phrase query: FOLLOWED BY operators <n>,<->
- Guarantee an order (and distance) of operands
- Precendence of tsquery operators - '! <-> & |'

```
select 'a:1 b:2'::tsvector @@ 'a <-> b'::tsquery,
       'a:1 b:2'::tsvector @@ 'b <-> a'::tsquery;
 ?column? | ?column?
----------+----------
 t        | f
```

Phrase search - properties

- Precendence of tsquery operators - '! <-> & |'
  Use parenthesis to control nesting in tsquery

```
select 'a & b <-> c'::tsquery;
      tsquery
-------------------
 'a' & 'b' <-> 'c'

select 'b <-> c & a'::tsquery;
      tsquery
-------------------
 'b' <-> 'c' & 'a'

 select 'b <-> (c & a)'::tsquery;
          tsquery
---------------------------
 'b' <-> 'c' & 'b' <-> 'a'
```

Phrase search - example

- `phraseto_tsquery([CFG,] TEXT)`

```
select phraseto_tsquery('english','PostgreSQL can be extended
by the user in many ways');
                     phraseto_tsquery
-----------------------------------------------------------
 'postgresql' <3> 'extend' <3> 'user' <2> 'mani' <-> 'way'
(1 row)
```

Stop words are taken into account !

- It’s possible to combine tsquery’s

```
select phraseto_tsquery('PostgreSQL can be extended by the user in many ways') ||
                  to_tsquery('oho<->ho & ik');
                              ?column?
-------------------------------------------------------------------------------------
 'postgresql' <3> 'extend' <3> 'user' <2> 'mani' <-> 'way' | 'oho' <-> 'ho' & 'ik'
(1 row)
```

Query processing

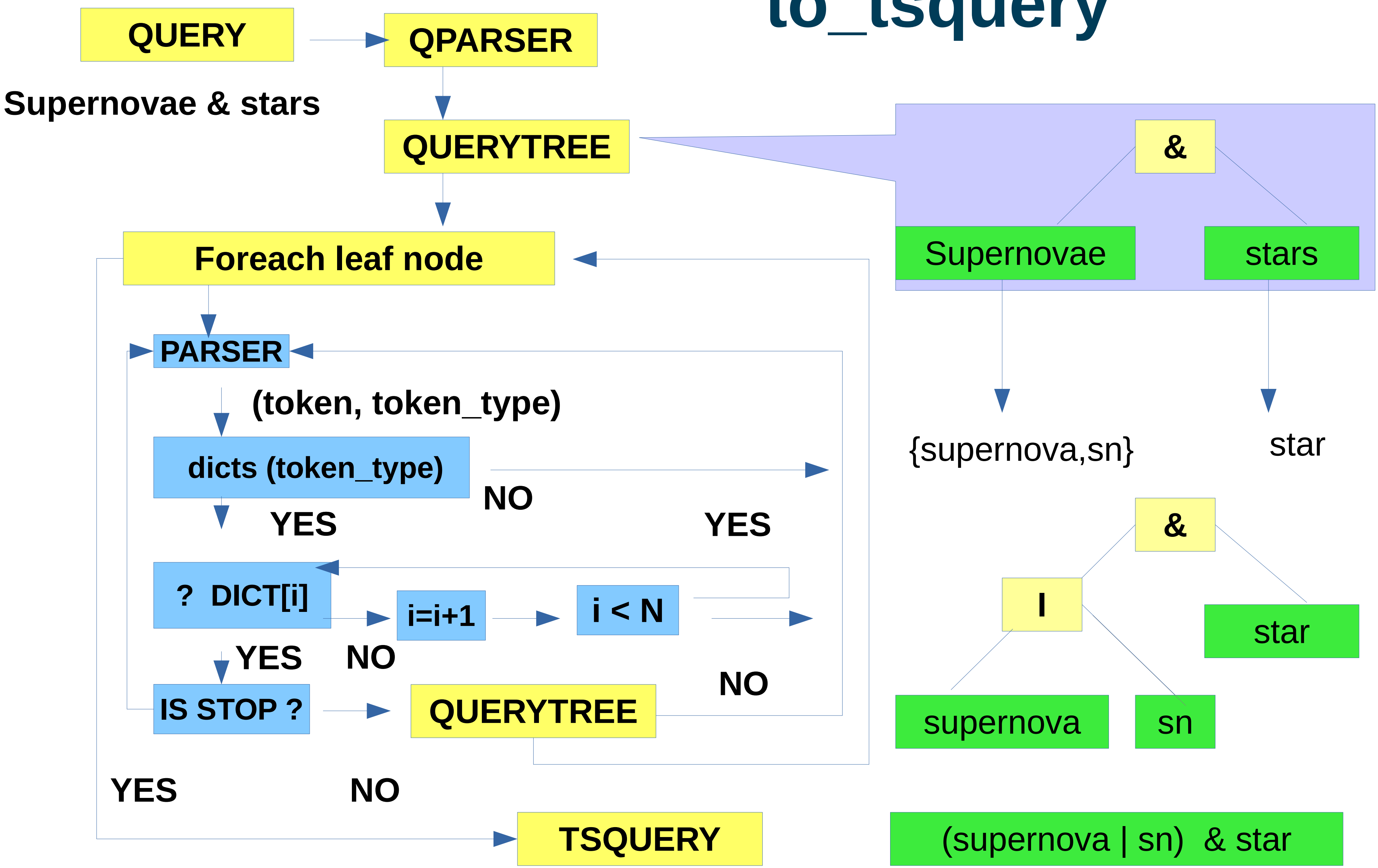
- websearch_to_tsquery([cfg], text)
  - Recognizes “phrases”, AND, OR, *, +word, -word

```
select websearch_to_tsquery('english','postgresql "open source *
database" -die +most');
                   websearch_to_tsquery
----------------------------------------------------------
 'postgresql' & 'open' <-> 'sourc' <2> 'databas' & !'die'
(1 row)


select to_tsvector('english', 'PostgreSQL: The Worlds Most Advanced
Open Source Relational Database') @@
websearch_to_tsquery('english','postgresql "open source * database" -
die +most');
 ?column?
----------
 t
(1 row)
```

FTS PostgreSQL

to_tsquery



FTS: additional functions

- ts_debug(cfg, text) – good for debugging FTS configuration
- ts_stat – word frequencies
- ts_parse(parser, text) – produces (token_type, token) from a text
- ts_rewrite – rewrite query online, no reindexing needed
- ts_headline – pieces of documents with words from query
- Ordering result of FTS:
  - ts_rank – the more occurrences of words,the bigger rank good for OR queries, no query language
  - ts_rank_cd – the closer words, the bigger rank good for AND queries, supports query language
  - rum_ts_score (requires RUM extension) – combination of the above, the best (NIST TREC, AD-HOC coll.)

FTS summary

- FTS in PostgreSQL is a flexible search engine,
- It is a «collection of bricks» you can build your search engine using
  - Custom parser
  - Custom dictionaries

  \+ All power of SQL (FTS+Spatial+Temporal)

Index — silver bullet !

the only weapon that is effective against a werewolf, witch, or other monsters.

Indexes !

- Index is a search tree with tuple pointers in the leaves
- Index has no visibility information (MVCC !)
- Indexes used only for accelerations:
  Index scan should produce the same results as sequence scan with filtering
- Indexes can be: **partial** (where price > 0.0), **functional** (to_tsvector(text)), **multicolumn** (timestamp, tsvector)
- Indexes not always useful !
  - Low selectivity
  - Maintainance overhead

FTS indexes

- CREATE INDEX … USING GIST/GIN/RUM (tsvector)
- GiST — Generalized Search Tree
  - document, query as a signature, documents → signature tree, Bloom filter used for search
- GIN — inverted tree, basically it“s a B-tree
  - Optimized for storing a lot of duplicate keys
  - Duplicates are ordered by heap TID
- RUM (extension)
  - GIN with addtional information (words positions, timestamp, ...)

Understanding GiST (array example)

- Intarray -Access Method for array of integers
  - Operators overlap, contains

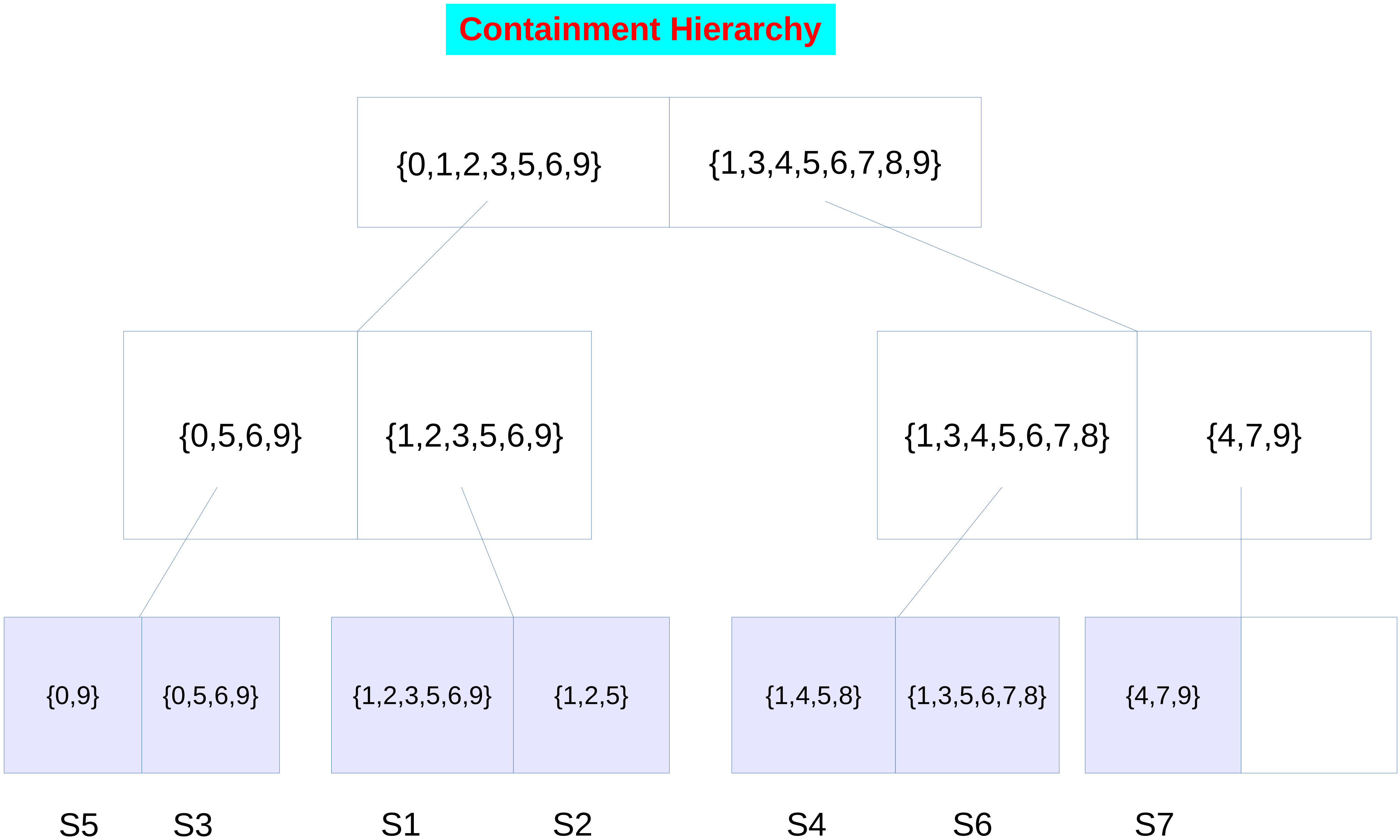
S1 = {1,**2**,3,5,6,**9**}
S2 = {1,**2**,5}
S3 = {0,5,6,**9**}
S4 = {1,4,5,8}
S5 = {0,9}
S6 = {3,5,6,7,8}
S7 = {4,7,**9**}

Q = {**2,9**}

Russian Doll Tree

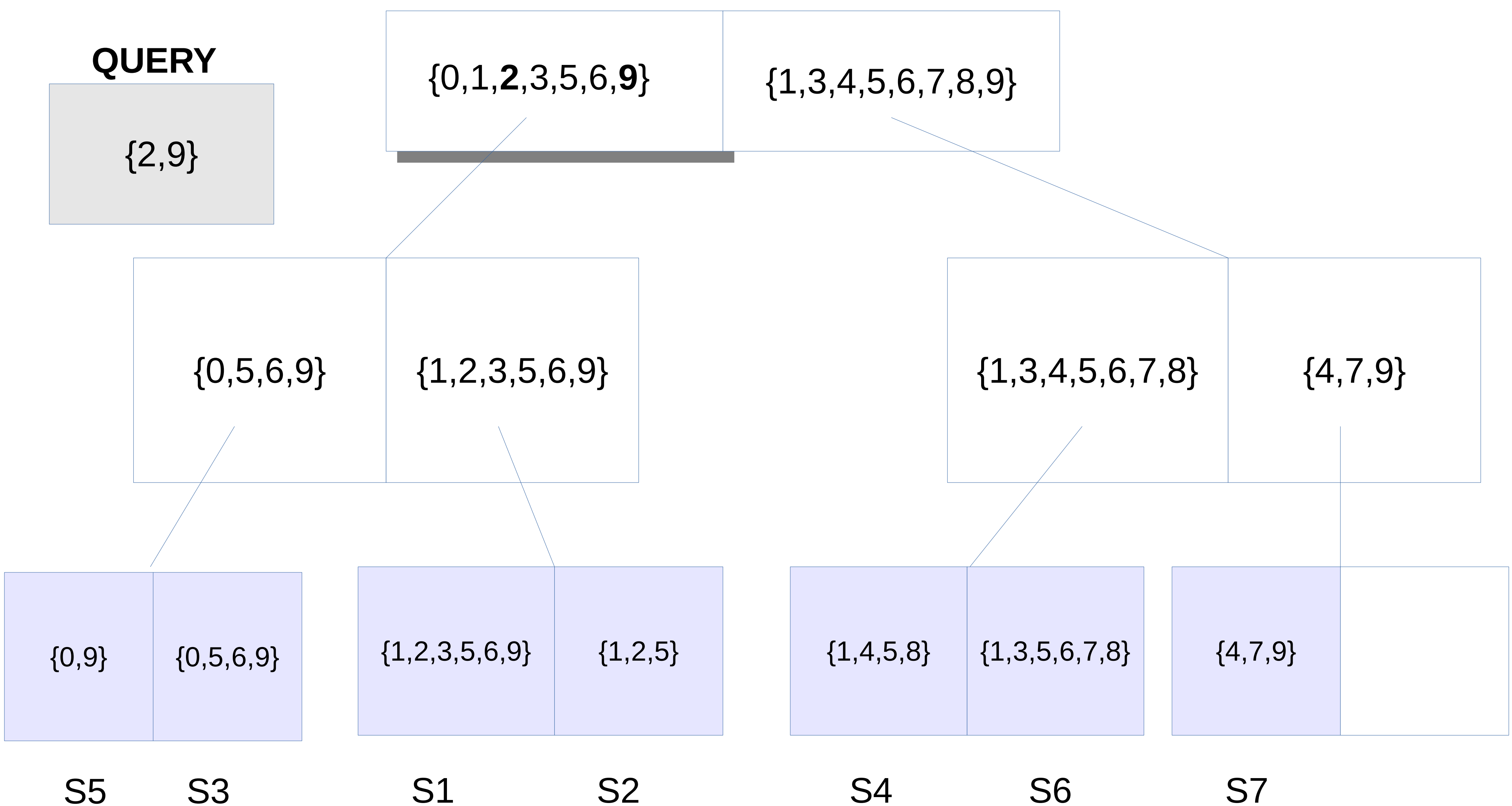
"THE RD-TREE: AN INDEX STRUCTURE FOR SETS", Joseph M. Hellerstein

RD-Tree

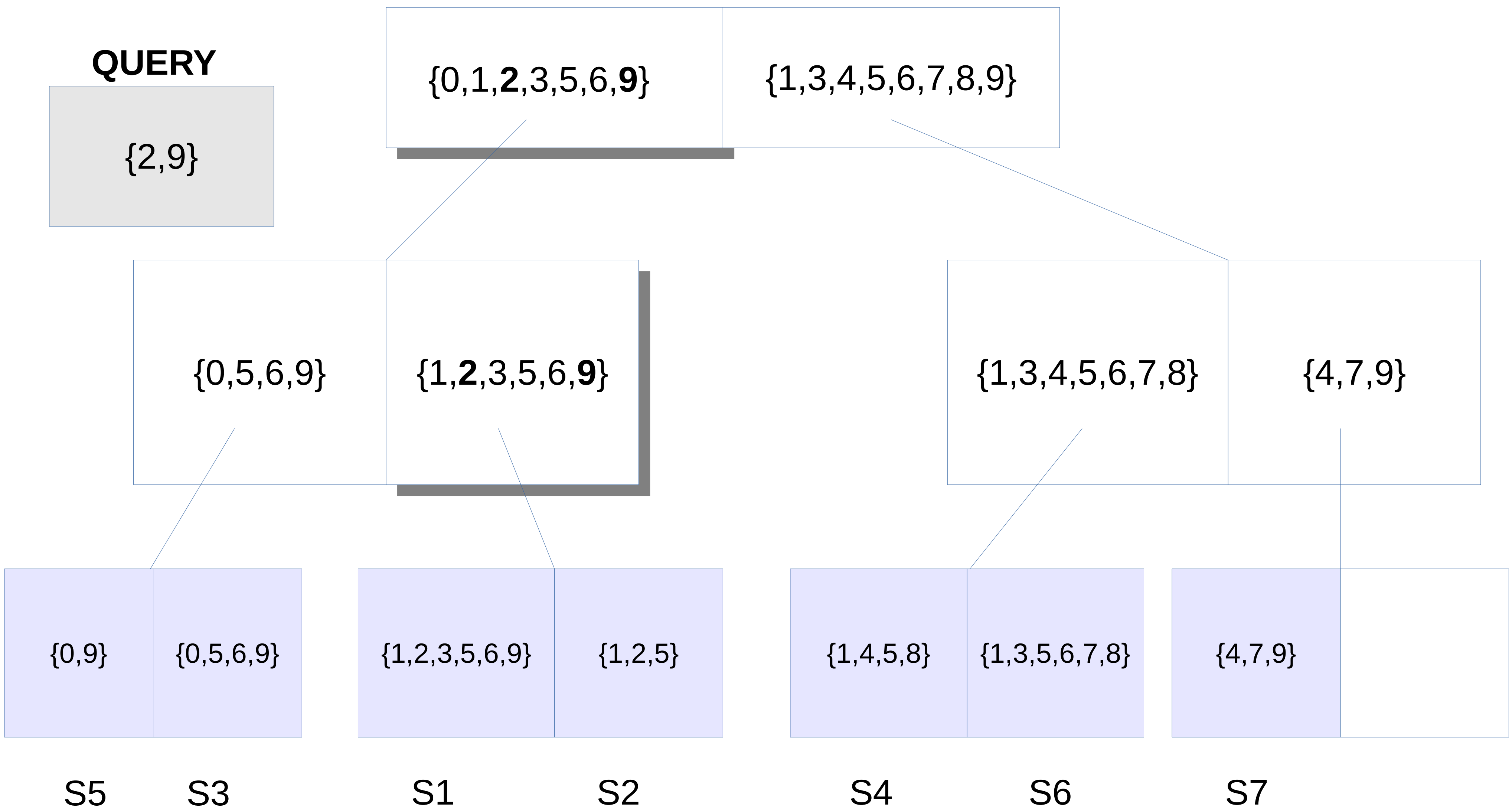


Containment Hierarchy
{0,1,2,3,5,6,9}
{1,3,4,5,6,7,8,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,3,4,5,6,7,8}
{4,7,9}
{0,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,2,5}
{1,4,5,8}
{1,3,5,6,7,8}
{4,7,9}
S5
S3
S1
S2
S4
S6
S7

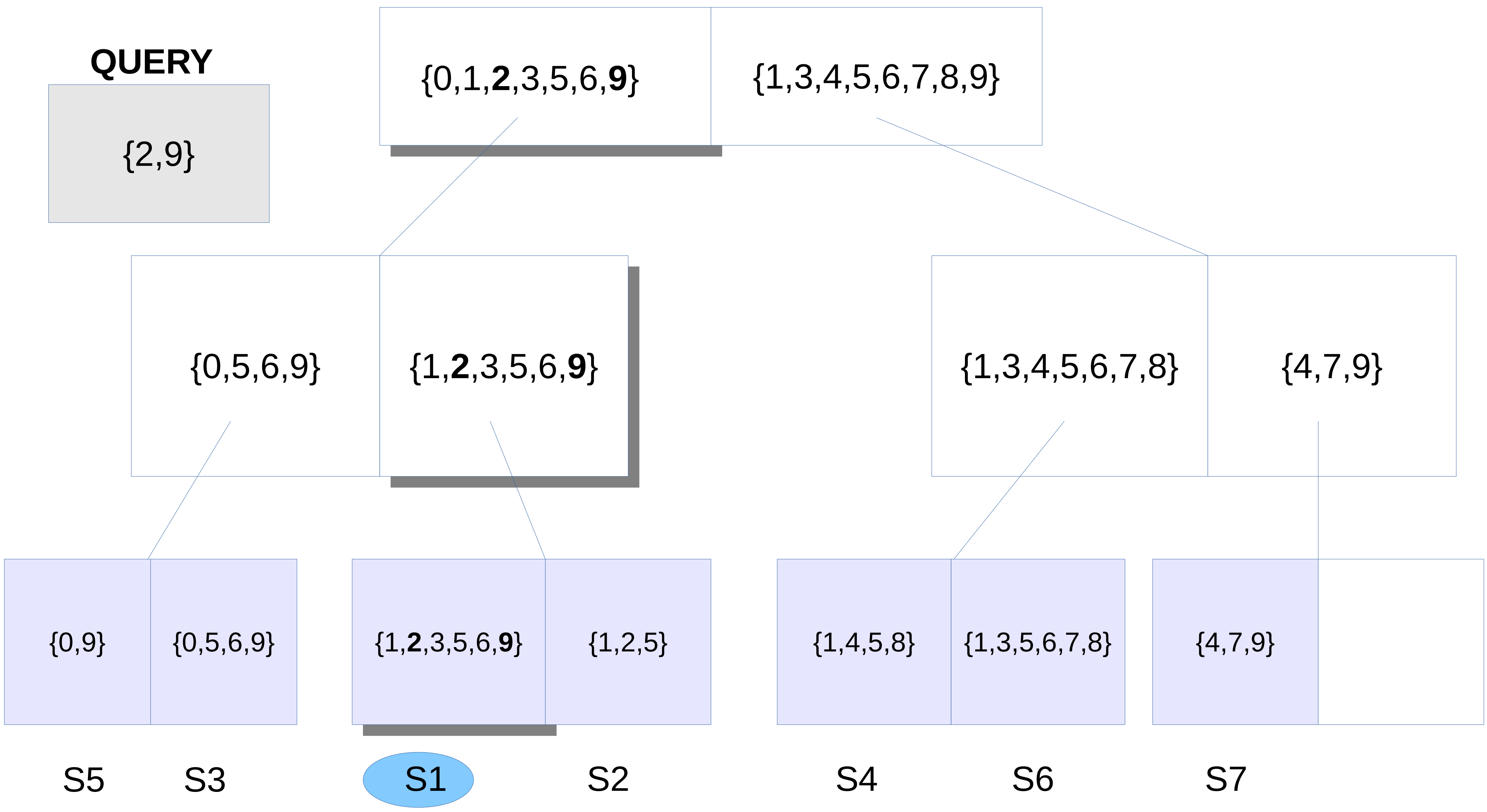
RD-Tree


QUERY
{2,9}
{0,1,**2**,3,5,6,**9**}
{1,3,4,5,6,7,8,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,3,4,5,6,7,8}
{4,7,9}
{0,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,2,5}
{1,4,5,8}
{1,3,5,6,7,8}
{4,7,9}
S5
S3
S1
S2
S4
S6
S7

RD-Tree


QUERY
{2,9}
{0,1,2,3,5,6,9}
{1,3,4,5,6,7,8,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,3,4,5,6,7,8}
{4,7,9}
{0,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,2,5}
{1,4,5,8}
{1,3,5,6,7,8}
{4,7,9}
S5
S3
S1
S2
S4
S6
S7

RD-Tree


QUERY
{2,9}
{0,1,2,3,5,6,9}
{1,3,4,5,6,7,8,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,3,4,5,6,7,8}
{4,7,9}
{0,9}
{0,5,6,9}
{1,2,3,5,6,9}
{1,2,5}
{1,4,5,8}
{1,3,5,6,7,8}
{4,7,9}
S5
S3
S1
S2
S4
S6
S7

FTS Index (GiST): RD-Tree

- Word signature — words hashed to the specific position of '1'

  w1 -> S1: 01000000 Document: w1 w2 w3

  w2 -> S2: 00010000

  w3 -> S3: 10000000

- Document (query) signature — superposition (bit-wise OR) of signatures

  S: 11010000

- Bloom filter

  Q1: 00000001 – exact not

  Q2: 01010000 - may be contained in the document, **false drop**

- Signature is a lossy representation of document
  - \+ fixed length, compact, + fast bit operations
  - \- lossy (false drops), - saturation with #words grows

FTS Index (GiST): RD-Tree

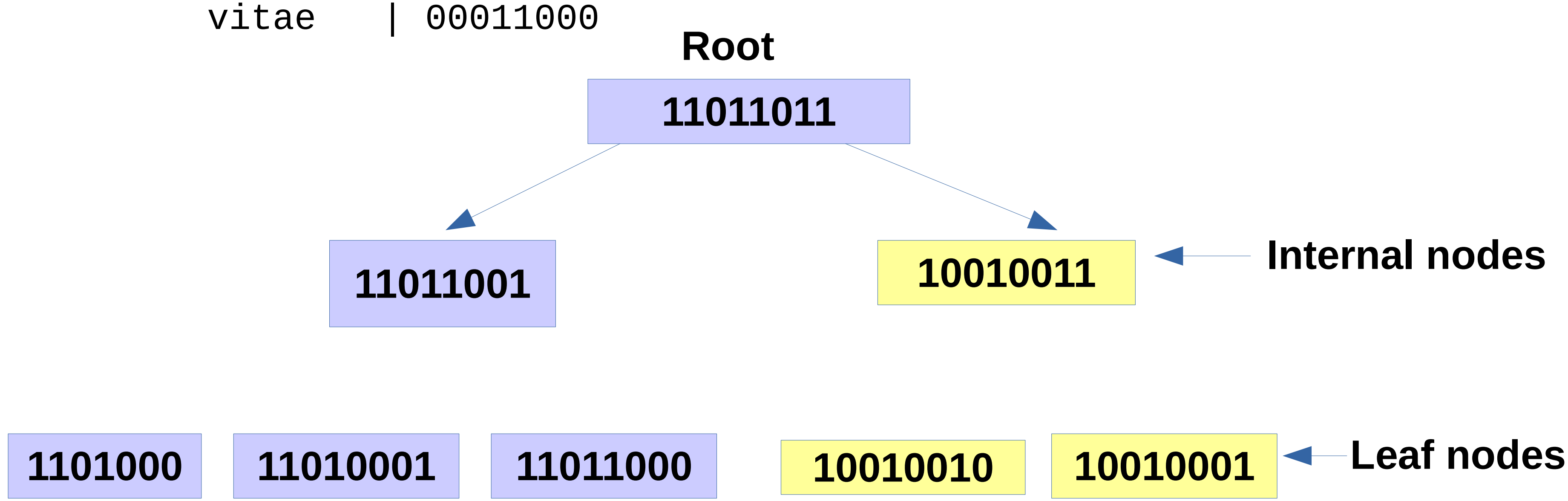
- Latin proverbs

```
id |          proverb
---+--------------------------
 1 | Ars longa, vita brevis
 2 | Ars vitae
 3 | Jus vitae ac necis
 4 | Jus generis humani
 5 | Vita nostra brevis
```

FTS Index (GiST): RD-Tree

```
    word    |  signature
---------+-----------
 ac         | 00000011
 ars        | 11000000
 brevis     | 00001010
 generis    | 01000100
 humani     | 00110000
 jus        | 00010001
 longa      | 00100100
 necis      | 01001000
 nostra     | 10000001
 vita       | 01000001
 vitae      | 00011000
```

QUERY



RD-Tree (GiST)

```
 id |          proverb           | signature
----+----------------------------+-----------
  1 | Ars longa, vita brevis     | 11101111
  2 | Ars vitae                  | 11011000
  3 | Jus vitae ac necis         | 01011011
  4 | Jus generis humani         | 01110101
  5 | Vita nostra brevis         | 11001011
```

False drop

RD-Tree (GiST)

- Problems
  - Not good scalabilty with increasing of cardinality of words and records.
  - Index is lossy, need check for false drops (Recheck в EXPLAIN ANALYZE)

GIN

Report Index

A

B

D

E

GIN

Report Index

A

B

E

QUERY: compensation accelerometers

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

RESULT: **30**

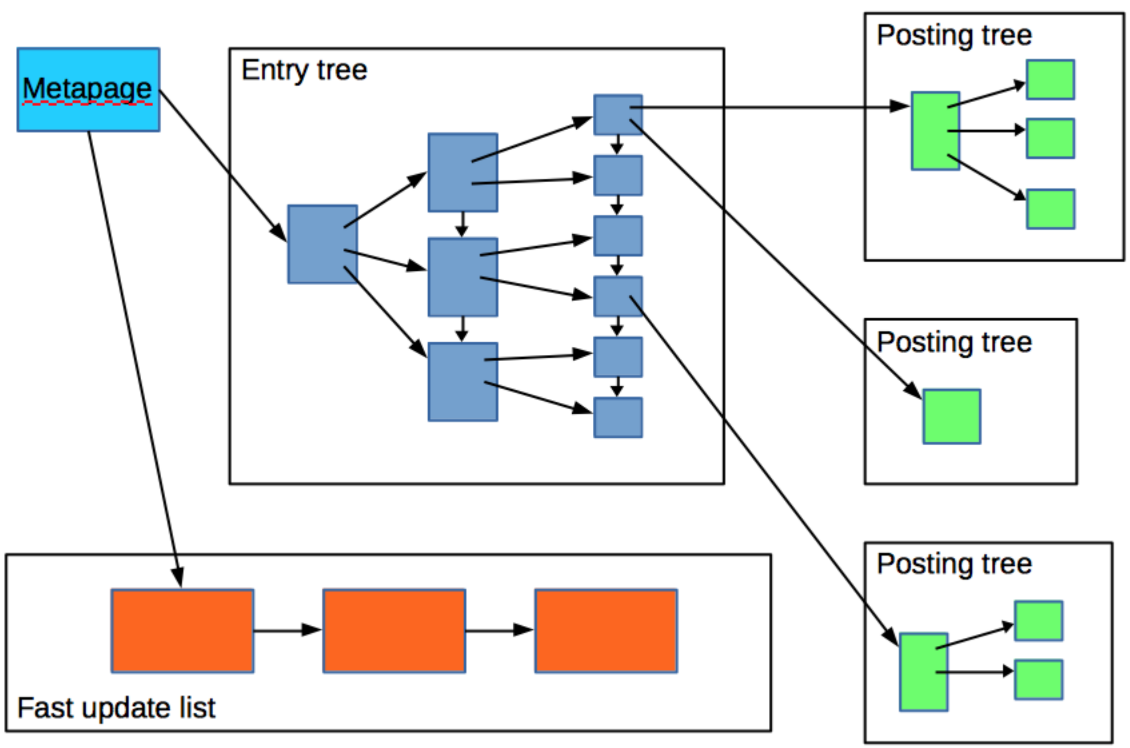
No positions in index !

Inverted Index in PostgreSQL

ENTRY TREE

Report Index

Posting list
Posting tree



GIN

- Internal structure is basically just a B-tree
  - Optimized for storing a lot of duplicate keys
  - Duplicates are ordered by heap TID
- Interface supports indexing more than one key per indexed value
  - Full text search: “foo bar” → “foo”, “bar”
- Bitmap scans only

GIN Index

Demo collections – latin proverbs

```
 id |         proverb
----+-----------------------------
  1 | Ars longa, vita brevis
  2 | Ars vitae
  3 | Jus vitae ac necis
  4 | Jus generis humani
  5 | Vita nostra brevis
```

GIN Index

Entry tree

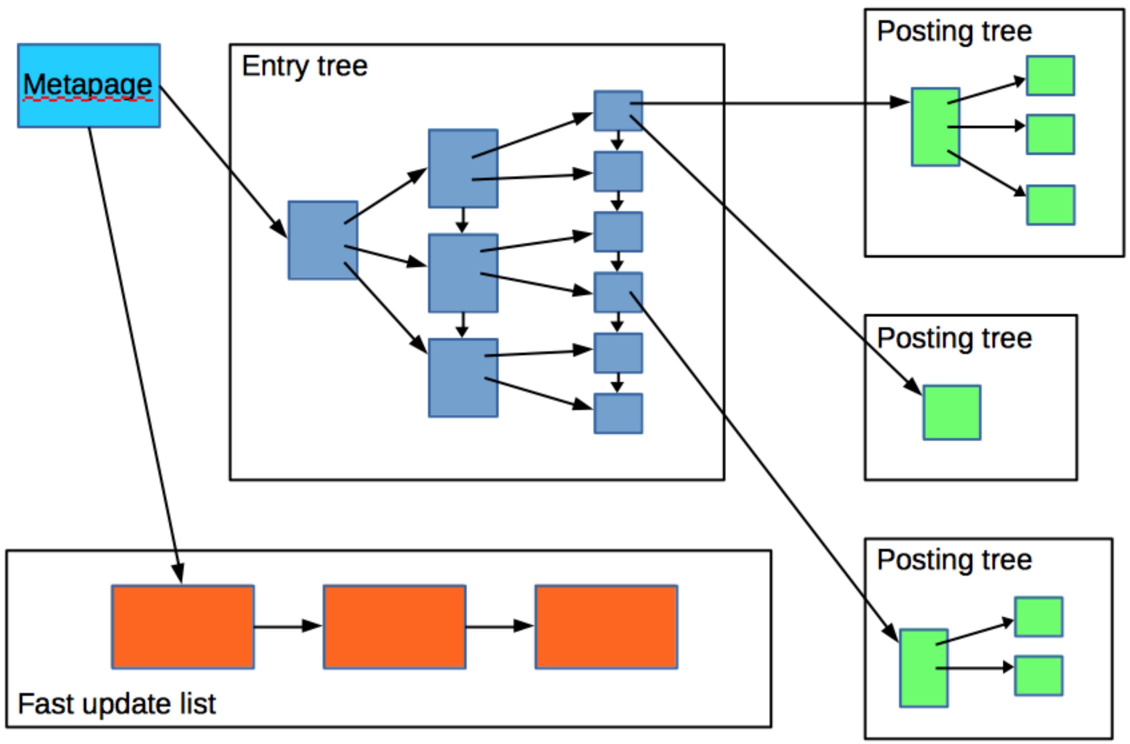
Inverted Index

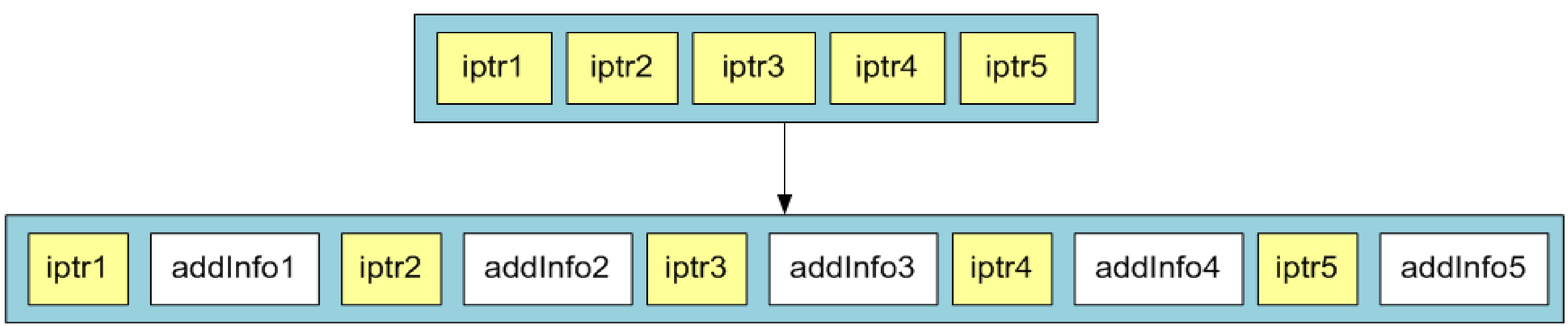
```
   word     | posting
----------+----------
  ac        | {3}
  ars       | {1,2}
  brevis    | {1,5}
  generis   | {4}
  humani    | {4}
  jus       | {3,4}
  longa     | {1}
  necis     | {3}
  nostra    | {5}
  vita      | {1,5}
  vitae     | {2,3}
```

Posting tree

- Fast search
- Slow update

RUM index (GIN ++)





RUM index

- Solve problem of slow ranking

postgres=# explain analyze
SELECT docid, ts_rank(text_vector, to_tsquery('english', 'title')) AS rank
FROM ti2
WHERE text_vector @@ to_tsquery('english', 'title')
ORDER BY rank DESC
LIMIT 3;

HEAP IS SLOW
400 ms !

```
 Limit  (cost=8087.40..8087.41 rows=3 width=282) (actua            3.752 rows=3 loops=1)
   ->  Sort  (cost=8087.40..8206.63 rows=47692 width=282)
(actual time=433.749..433.749 rows=3 loops=1)
         Sort Key: (ts_rank(text_vector, '''titl'''::tsquery))
         Sort Method: top-N heapsort  Memory: 25kB
         ->  Bitmap Heap Scan on ti2  (cost=529.61..7470.99 rows=47692 width=282)
(actual time=15.094..423.452 rows=47855 loops=1)
               Recheck Cond: (text_vector @@ '''titl'''::tsquery)
               ->  Bitmap Index Scan on ti2_index  (cost=0.00..517.69 rows=47692 width=0)
(actual time=13.736..13.736 rows=47855 loops=1)
                     Index Cond: (text_vector @@ '''titl'''::tsquery)
 Total runtime: 433.787 ms
```

Improve ranking performance

- Store positions in RUM to calculate rank and order results
- Introduce distance operator tsvector <-> tsquery

```
CREATE INDEX ti2_rum_fts_idx ON ti2 USING rum(text_vector rum_tsvector_ops);

SELECT docid, ts_rank(text_vector, to_tsquery('english', 'title')) AS rank
FROM ti2
WHERE text_vector @@ to_tsquery('english', 'title')
ORDER BY
text_vector <-> plainto_tsquery('english','title') LIMIT 3;
                                       QUERY PLAN
----------------------------------------------------------------------------------------
 Limit (actual time=13.843..13.884 rows=3 loops=1)
   ->  Index Scan using ti2_rum_fts_idx on ti2 (actual time=13.841..13.881 rows=3 loops=1)
         Index Cond: (text_vector @@ '''titl'''::tsquery)
         Order By: (text_vector <-> '''titl'''::tsquery)
 Planning time: 0.134 ms
 Execution time: 14.030 ms vs 433 ms !
(6 rows)
```

Combine FTS with ordering by timestamp

Search for «fresh» documents

```
select date,  subject from msg
where tsvector @@ to_tsquery('server & crashed')
order by date <=| '2000-01-01'::timestamp limit 5;
```

```
Limit (actual time=12.089..12.091 rows=5 loops=1)
   ->  Sort (actual time=12.088..12.089 rows=5 loops=1)
         Sort Key: ((date < '2000-01-01 00:00:00'::timestamp without time zone))
         Sort Method: top-N heapsort  Memory: 25kB
         ->  Bitmap Heap Scan on msg (actual time=5.285..10.784 rows=7467 loops=1)
               Recheck Cond: (tsvector @@ to_tsquery('server & crashed'::text))
               Heap Blocks: exact=6927
               ->  Bitmap Index Scan on msg_gin_idx (actual time=4.196..4.196 rows=7467
loops=1)
                     Index Cond: (tsvector @@ to_tsquery('server & crashed'::text))
 Planning Time: 0.153 ms
 Execution Time: 12.121 ms
(11 rows)
```

Combine FTS with ordering by timestamp

- Combine FTS with ordering by timestamp
  - Store timestamps in additional information
  - Order posting tree/list by timestamp

```
create index msg_date_rum_idx on msg using rum(tsvector
rum_tsvector_timestamp_ops, date) WITH
(attach=date, "to"=tsvector, order_by_attach='t');

select date,  subject from msg
where tsvector @@ to_tsquery('server & crashed')
order by date <=| '2000-01-01'::timestamp limit 5;

 Limit (actual time=0.048..0.071 rows=5 loops=1)
   ->  Index Scan using msg_date_rum_idx on msg (actual
time=0.047..0.069 rows=5 loops=1)
         Index Cond: (tsvector @@ to_tsquery('server &
crashed'::text))
         Order By: (date <=| '2000-01-01 00:00:00'::timestamp without
time zone)
 Planning Time: 0.196 ms
 Execution Time: 0.095 ms vs 12.21 !
(6 rows)
```

RUM improves phrase search

- 1.1 mln postings
  Overhead of phrase search for seqscan is not big

select count(*) from pglist where fts @@ to_tsquery('english','tom <-> lane');
 count

 222777
(1 row)

Sequential Scan: phrase 1.7 s vs 1.6 s (&)

```
select count(*) from pglist where fts @@ to_tsquery('english', 'tom <-> lane');
                                           QUERY PLAN
--------------------------------------------------------------------------------
 Finalize Aggregate (actual time=1700.280..1700.280 rows=1 loops=1)
   ->  Gather (actual time=1700.228..1700.277 rows=3 loops=1)
         Workers Planned: 2
         Workers Launched: 2
         ->  Partial Aggregate (actual time=1696.119..1696.119 rows=1 loops=3)
               ->  Parallel Seq Scan on pglist (actual time=2.356..1683.499 rows=74259
loops=3)
                     Filter: (fts @@ '''tom'' <-> ''lane'''::tsquery)
                     Rows Removed by Filter: 263664
 Planning time: 0.270 ms
 Execution time: 1709.092 ms
(10 rows)
```

RUM improves phrase search

- 1.1 mln postings
  Overhead of phrase search for index scan is big !

GIN index (1.1 s (<->) vs 0.48 s (&)): Use recheck, phrase is slow vs fts

```
select count(*) from pglist where fts @@ to_tsquery('english', 'tom <-> lane');
                                                  QUERY PLAN
------------------------------------------------------------------------------------
 Aggregate (actual time=1074.983..1074.984 rows=1 loops=1)
   ->  Bitmap Heap Scan on pglist (actual time=84.424..1055.770 rows=222777 loops=1)
         Recheck Cond: (fts @@ '''tom'' <-> ''lane'''::tsquery)
         Rows Removed by Index Recheck: 36
         Heap Blocks: exact=105992
         ->  Bitmap Index Scan on pglist_gin_idx (actual time=53.628..53.628 rows=222813
loops=1)
               Index Cond: (fts @@ '''tom'' <-> ''lane'''::tsquery)
 Planning time: 0.329 ms
 Execution time: 1075.157 ms
(9 rows)
```

RUM improves phrase search

- 1.1 mln postings
  RUM descreases the overhead of phrase search !

RUM index (0.5 s (<-> vs 0.48 s (&)): Use positions in addinfo, no overhead of phrase search !

```
select count(*) from pglist where fts @@ to_tsquery('english', tom <-> lane');
                                              QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate (actual time=513.517..513.517 rows=1 loops=1)
   ->  Bitmap Heap Scan on pglist (actual time=134.109..497.814 rows=221919 loops=1)
         Recheck Cond: (fts @@ to_tsquery('tom <-> lane'::text))
         Heap Blocks: exact=105509
         ->  Bitmap Index Scan on pglist_rum_fts_idx (actual time=98.746..98.746
rows=221919 loops=1)
               Index Cond: (fts @@ to_tsquery('tom <-> lane'::text))
 Planning time: 0.223 ms
 Execution time: 515.004 ms
(8 rows)
```

Inverse FTS (FQS)

- Find queries, which match given document
  - Automatic text classification, subscription service

```
SELECT * FROM queries;
                 q                 |  tag
-----------------------------------+-------
 'supernova' & 'star'              | sn
 'black'                           | color
 'big' & 'bang' & 'black' & 'hole' | bang
 'spiral' & 'galaxi'               | shape
 'black' & 'hole'                  | color
(5 rows)


SELECT * FROM queries WHERE
 to_tsvector('black holes never exists before we think about them')
@@ q;
        q         |  tag
------------------+-------
 'black'          | color
 'black' & 'hole' | color
(2 rows)
```

Inverse FTS (FQS)

- RUM index – store branches of query tree in addinfo

Find queries for the first message in postgres mailing lists

```
\d pg_query
   Table "public.pg_query"
 Column |  Type    | Modifiers
--------+---------+-----------
 q      | tsquery |
 count  | integer |
Indexes:
    "pg_query_rum_idx" rum (q)                33818 queries


select q from pg_query pgq, pglist where q @@ pglist.fts and pglist.id=1;
             q
--------------------------
 'one' & 'one'
 'postgresql' & 'freebsd'
(2 rows)
```

Inverse FTS (FQS)

- RUM index support – store branches of query tree in addinfo

Find queries for the first message in postgres mailing lists

```
create index pg_query_rum_idx on pg_query using rum(q);
select q from pg_query pgq, pglist where q @@ pglist.fts and pglist.id=1;
                                          QUERY PLAN
--------------------------------------------------------------------------
 Nested Loop (actual time=0.719..0.721 rows=2 loops=1)
   ->  Index Scan using pglist_id_idx on pglist
(actual time=0.013..0.013 rows=1 loops=1)
         Index Cond: (id = 1)
   ->  Bitmap Heap Scan on pg_query pgq
(actual time=0.702..0.704 rows=2 loops=1)
         Recheck Cond: (q @@ pglist.fts)
         Heap Blocks: exact=2
         ->  Bitmap Index Scan on pg_query_rum_idx
(actual time=0.699..0.699 rows=2 loops=1)
               Index Cond: (q @@ pglist.fts)
 Planning time: 0.212 ms
 Execution time: 0.759 ms
(10 rows)
```

Inverse FTS (FQS)

- RUM index supported – store branches of query tree in addinfo

Monstrous postings

```
select id, t.subject, count(*) as cnt into pglist_q  from pg_query,
(select id, fts, subject from pglist) t where t.fts @@ q
group by id, subject order by cnt desc limit 1000;

select * from pglist_q  order by cnt desc limit 5;
   id   |                       subject                       | cnt
--------+-----------------------------------------------+------
 248443 | Packages patch                                | 4472
 282668 | Re: release.sgml, minor pg_autovacuum changes | 4184
 282512 | Re: release.sgml, minor pg_autovacuum changes | 4151
 282481 | release.sgml, minor pg_autovacuum changes     | 4104
 243465 | Re: [HACKERS] Re: Release notes               | 3989
(5 rows))
```

RUM size, create index

- 1.1 mln posts

  msg (id, list, subject, author, body, tsvector, date)

```
GiST: create index msg_gist_idx on msg using gist(tsvector);
GIN:  create index msg_gin_idx on msg using gin(tsvector);
RUM: create index msg_rum_idx on msg using rum(tsvector);
RUM: create index msg_rum_date_idx on msg using rum(tsvector
rum_tsvector_timestamp_ops, date) WITH (attach=date, "to"=tsvector);
RUM: create index msg_date_rum_idx on msg using rum(tsvector
rum_tsvector_timestamp_ops, date) WITH
(attach=date, "to"=tsvector, order_by_attach='t');
```

RUM size, create index

- 1.1 mln posts
  - Size and create index (sec)

```
select pg_size_pretty(pg_table_size('msg')) as msg,
       pg_size_pretty(sum(pg_column_size(tsvector))) as fts,
       pg_size_pretty(pg_table_size('msg_gist_idx')) as gist,
       pg_size_pretty(pg_table_size('msg_gin_idx')) as gin,
       pg_size_pretty(pg_table_size('msg_rum_idx')) as rum,
       pg_size_pretty(pg_table_size('msg_rum_date_idx')) as rum_date,
       pg_size_pretty(pg_table_size('msg_date_rum_idx')) as date_rum from msg;


   msg    | tsvector|  gist   |  gin    |   rum    | rum_date | date_rum
---------+---------+--------+--------+---------+----------+----------
 3178 MB | 1558 MB | 394 MB | 462 MB | 1130 MB | 1812 MB  | 2596 MB
(1 row)
 318                  49         112       215       229           706     (sec)
```

FTS indexes

- GiST
  - document, query as a signature, documents → signature tree, Bloom filter used for search
  - Fast insert, small size, good for small collections
- GIN — inverted tree, basically it“s a B-tree
  - Optimized for storing a lot of duplicate keys
  - Duplicates are ordered by heap TID
  - Not as fast as GiST for updates, good performance and scalability
- RUM (extension) — GIN++
  - Slow for updating, big size, high WAL traffic, best for mostly read workload, very fast for ranking, good for phrase search, no need tsvector column

Ispell shared dictionaries

- Working with dictionaries can be difficult and slow
  - Installing dictionaries can be complicated
  - Dictionaries are loaded into memory for every session (slow first query symptom) and eat memory.

```
time for i in {1..10}; do echo $i; psql postgres -c "select
ts_lexize('english_hunspell', 'evening')" > /dev/null;  done
1
2
3
4
5
6
7
8
9
10

real	0m0.656s
user	0m0.015s
sys	0m0.031s
```

For russian hunspell dictionary:

real 0m3.809s
user0m0.015s
sys 0m0.029s

Each session «eats» 20MB !

Dictionaries as extensions

- Easy installation of hunspell dictionaries

```
CREATE EXTENSION hunspell_ru_ru; -- creates russian_hunspell dictionary
CREATE EXTENSION hunspell_en_us; -- creates english_hunspell dictionary
CREATE EXTENSION hunspell_nn_no; -- creates norwegian_hunspell dictionary
SELECT ts_lexize('english_hunspell', 'evening');
   ts_lexize
----------------
 {evening,even}
(1 row)

Time: 57.612 ms
SELECT ts_lexize('russian_hunspell', 'туши');
       ts_lexize
------------------------
 {туша,тушь,тушить,туш}
(1 row)

Time: 382.221 ms
SELECT ts_lexize('norwegian_hunspell','fotballklubber');
           ts_lexize
--------------------------------
 {fotball,klubb,fot,ball,klubb}
(1 row)

Time: 323.046 ms
```

Slow first query syndrom

Dictionaries in shared memory

```
CREATE EXTENSION shared_ispell;
CREATE TEXT SEARCH DICTIONARY english_shared (
    TEMPLATE = shared_ispell,
    DictFile = en_us,
    AffFile = en_us,
    StopWords = english
);
CREATE TEXT SEARCH DICTIONARY russian_shared (
    TEMPLATE = shared_ispell,
    DictFile = ru_ru,
    AffFile = ru_ru,
    StopWords = russian
);
time for i in {1..10}; do echo $i; psql postgres -c "select ts_lexize('russian_shared', 'туши')" > /dev/null;  done
1
2
…..
10
```

real 0m0.170s user 0m0.015s sys 0m0.027s	VS	real 0m3.809s user0m0.015s sys 0m0.029s	

PROFESSIONAL Postgres

Search Mailing list archive

- https://postgrespro.com/list
- Custom parser — fixes several problems in default parser

```
select * from ts_parse('default','1914-1999');
 tokid | token
-------+-------
    22 | 1914
    21 | -1999
(2 rows)
```

```
select * from ts_parse('tsparser','1914-1999');
 tokid |   token
-------+-----------
    15 | 1914-1999
     9 | 1914
    12 | -
     9 | 1999
(4 rows)
```

```
select * from ts_parse('default','pg_catalog');
 tokid |  token
-------+---------
     1 | pg
    12 | _
     1 | catalog
(3 rows)
```

```
select * from ts_parse('tsparser','pg_catalog');
 tokid |   token
-------+------------
    16 | pg_catalog
    11 | pg
    12 | _
    11 | catalog
(4 rows)
```

Search Mailing list archive

- https://postgrespro.com/list
- Faceted search - grouping search results by lists
- Strip citation from posts
- Uses pg_trgm for suggestions
- Advanced query language
  - Support «phrase» search

Search Mailing list archive

server cras | Mailing lists | Search

server crash
server crashes
server crashing
server crashed
server crashme

server crash - Search results in mailing lists

server crash

List
All lists

Post date
anytime

Sort by
Date

Search

pgsql-general (1037)

2018-10-16 21:25:54 | postgres **server** process **crashes** when using odbc_fdw (Ravi Krishna)

server. I also created foreign table. When I run a sql 'select * from odbctest' postgres **crashes**

Thread >> Search in thread (12)

2018-09-26 14:46:10 | Re: Setting up continuous archiving (Stephen Frost)

server crashes or there's some kind of issue with it after the rsync finishes

Thread

2018-08-29 04:02:45 | WAL replay issue from 9.6.8 to 9.6.10 (Dave Peticolas)

server to 9.6.8 and I was able to replay WAL past the point where 9.6.10 would PANIC and **crash**

Thread

2018-08-24 19:07:41 | Re: unorthodox use of PG for a customer (David Gauthier)

crash them. Of course any DB running would die too and have to be restarted/recovered. So the place for the DB is really elsewhere, on an external **server**

Thread

pgsql-hackers (1199)

2018-10-23 21:06:49 | Re: [HACKERS] Transactions involving multiple postgres foreignservers, take 2 (Masahiko Sawada)

References

- Slides of this talk
  http://www.sai.msu.su/~megera/postgres/talks/pgconf.eu-2018-fts.pdf
- Text search documentation
  http://www.postgresql.org/docs/current/static/textsearch.html
- Dictionaries as extensions
  https://github.com/postgrespro/hunspell_dicts
- Improved text search parser
  https://github.com/postgrespro/pg_tsparser
- RUM access method
  https://github.com/postgrespro/rum
- Shared ispell template
  https://github.com/postgrespro/shared_ispell
- Full text search example
  https://github.com/postgrespro/apod_fts
- Dictionary for regular expressions
  https://github.com/obartunov/dict_regex
- Setrank - TF*IDF ranking
  https://github.com/obartunov/setrank

References

- Dictionary for roman numbers
  https://github.com/obartunov/dict_roman
- Faceted search in one query
  http://akorotkov.github.io/blog/2016/06/17/faceted-search/
- FTS real example: Search mailing list archives
  https://postgrespro.com/list
- FTS slides with a lot of info
  http://www.sai.msu.su/~megera/postgres/talks/fts_postgres_by_authors_2.pdf
- Pg_trgm documentation
  https://www.postgresql.org/docs/11/static/pgtrgm.html
- My postings about FTS
  https://obartunov.livejournal.com/tag/fts

Agradeço a vossa atenção !