Ditch Elasticsearch and Use a Real Database for Text Search

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About me

- Systems & Database Architect
- Based in Edinburgh, Scotland
- Open Source user & contributor (25+ years)
- PostgreSQL exclusively (16+ years)
- Author, PostgreSQL Mistakes and How to Avoid Them
- Co-author, PostgreSQL 16 Administration Cookbook
- **`pg_statviz`** PostgreSQL extension

Contents

- Full Text Search
- Operators
- Functions
- Dictionaries
- Examples
- Indexing
- Collations
- Other “text” types

Your attention please

Allergy advice

- This presentation mentions **linguistics, NLP, Markov chains, Levenshtein distances,** and various other **confounding terms.**
- These have been known to induce **drowsiness** and **inappropriate sleep onset** in lecture theatres.

Motivation, clickbait, etc.

- Elasticsearch is not a database!
- Indexing is slow
  - You need to change the configuration depending on expected length
- Synchronisation
- You value consistency (look up **ACID**)
- You value license consistency (look up **PostgreSQL license**)

What is text?

- PostgreSQL character types
  - CHAR(n)
  - VARCHAR(n)
  - VARCHAR, TEXT
- Trailing spaces: significant (e.g. for LIKE / regex)
- Storage
  - Character Set (e.g. UTF-8)
  - 1+126 bytes → 4+n bytes
  - Compression, TOAST

What is text search?

- Search on metadata
  - Descriptive, bibliographic, tags, etc.
  - Discovery & identification
- Search on parts of the text
  - Matching
  - Substring search
  - Data extraction, cleaning, mining

Text search operators in PostgreSQL

- `LIKE`, `ILIKE` (`~~`, `~~*`)
- `~`, `~*` (POSIX regex)
- `regexp_match(string text, pattern text)`
- `SIMILAR TO`
  - Best forget about this one
  - SQL standard regexps
- But are SQL/regular expressions enough?
  - No ranking of results
  - No concept of language
  - Cannot be indexed
  - Okay, can be somewhat indexed*

What is Full Text Search (FTS)?

- Search on words (on tokens) in a database (all documents)
- No index: Serial search (e.g. grep)
- Indexing to avoid scanning whole documents
- Precision vs Recall
  - Stop words
  - Stemming
- Techniques for criteria-based matching and extraction
  - Natural Language Processing (NLP)
  - AI / LLMs

Documents, Tokens, etc.

- Document: a chunk of text (a field in a row)
- Parsing of documents into classes of *tokens*
  - PostgreSQL parser (or write your own… in C)
- Conversion of tokens into *lexemes*
  - *Normalisation* of strings
- Lexeme: abstract lexical unit representing related words (i.e. word root)
- `searched, searcher`
  ➡ `SEARCH`

Stop words

- Very common
- Have no value for our search
- Filtering them out increases **precision** of search
- Removal based on dictionaries
  - Some check stoplist first
- But: phrase search?

Stemming

- Reducing words to their roots (lexemes)
- Increases number of results (**recall**)

- Algorithms
  - Normalisation using dictionaries
  - Prefix/suffix stripping
  - Automatic production rules
  - Lemmatisation rules
  - N-gram models
- Multilingual stemming?

FTS representation in Postgres

- `tsvector`
  - A document
  - Preprocessed
- `tsquery`
  - Our search query
  - Normalized into lexemes

- Utility functions
  - `to_tsvector()`, `plainto_tsquery()`, `ts_debug()`, etc.

FTS operators in Postgres

`@@`	`tsvector` matches `tsquery`
`||`	`tsvector` concatenation
`&&`, `||`, `!!`	`tsquery` `AND`, `OR`, `NOT`
`<->`	`tsquery` followed by `tsquery`
`@>`	`tsquery` contains
`<@`	`tsquery` is contained in

Dictionaries in PostgreSQL

- Programs that accept tokens as input
- Improve search quality
  - Eliminate stop words
  - Normalise words into lexemes
  - Reduce size of tsvector
- `CREATE TEXT SEARCH DICTIONARY <name> (TEMPLATE = simple, STOPWORDS = english);`
- Can be chained
  - Most specific → more general
  - `ALTER TEXT SEARCH CONFIGURATION <name> ADD MAPPING FOR word WITH english_ispell, simple;`
- `ispell`, `myspell`, `hunspell`, etc.

Text matching example

```
fts=# SELECT to_tsvector('A nice day for a car ride') @@ plainto_tsquery('I am riding');
 ?column?
----------
 t
(1 row)

fts=# SELECT to_tsvector('A nice day for a car ride');
            to_tsvector
-----------------------------------
 'car':6 'day':3 'nice':2 'ride':7
(1 row)

fts=# SELECT plainto_tsquery('I am riding');
 plainto_tsquery
-----------------
 'ride'
(1 row)
```

Text matching example (ii)

```
fts=# SELECT to_tsvector('A nice day for a car ride') @@ plainto_tsquery('I am riding a bike');
 ?column?
----------
 f
(1 row)

fts=# SELECT to_tsvector('A nice day for a car ride');
            to_tsvector
-----------------------------------
 'car':6 'day':3 'nice':2 'ride':7
(1 row)

fts=# SELECT plainto_tsquery('I am riding a bike');
 plainto_tsquery
-----------------
 'ride' & 'bike'
(1 row)
```

Text matching example (iii)

```
fts=# SELECT 'Starman' @@ 'star';
 ?column?
----------
 f
(1 row)

fts=# SELECT 'Starman' @@ to_tsquery('star:*');
 ?column?
----------
 t
(1 row)

fts=# SELECT websearch_to_tsquery('"The Stray Cats" -"cat shelter"');
             websearch_to_tsquery
-----------------------------------------------
 'stray' <-> 'cat' & !( 'cat' <-> 'shelter' )
(1 row)
```

An example table

- `pgsql-hackers` mailing list archive subset

```
fts=# \d mail_messages
                                        Table "public.mail_messages"
   Column   |            Type             | Collation | Nullable |                  Default
------------+-----------------------------+-----------+----------+-------------------------------------------
 id         | integer                     |           | not null | nextval('mail_messages_id_seq'::regclass)
 parent_id  | integer                     |           |          |
 sent       | timestamp without time zone |           |          |
 subject    | text                        |           |          |
 author     | text                        |           |          |
 body_plain | text                        |           |          |

fts=# \dt+ mail_messages
                                  List of relations
 Schema |     Name      | Type  |  Owner   |  Size  | Description
--------+---------------+-------+----------+--------+-------------
 public | mail_messages | table | postgres | 478 MB |
```

Ranking results

`ts_rank` (and Cover Density variant `ts_rank_cd`)

```
fts=# SELECT subject, ts_rank(to_tsvector(coalesce(body_plain,'')),
fts(# to_tsquery('aggregate'), 32) AS rank
fts-# FROM mail_messages ORDER BY rank DESC LIMIT 5;
```

subject	rank
Re: Window functions patch v04 for the September commit fest	0.08969686
Re: Window functions patch v04 for the September commit fest	0.08940695
Re: [HACKERS] PoC: Grouped base relation	0.08936066
Re: [HACKERS] PoC: Grouped base relation	0.08931142
Re: [PERFORM] not using index for select min(...)	0.08925897

Text indexing

- Normal default:
  - B-Tree
  - With B-Tree `text_pattern_ops` for left, right anchored text
  - `CREATE INDEX <name> ON table (<column> varchar_pattern_ops);`
- For FTS we have:
  - **GIN**: Inverted index: one entry per lexeme
    - Larger, slower to update, better on less dynamic data
    - On `tsvector` columns
  - **GiST**: Lossy index, smaller but slower (to eliminate false positives)
    - Better on fewer unique items
    - On `tsvector` or `tsquery` columns

GIN, GiST indexed operations

- GIN
  - `tsvector: @@`
  - `jsonb: ? ?& ?| @> @? @@`
- GiST
  - `tsvector: @@`
  - `tsquery: <@ @>`

FTS, unindexed

```
fts=# EXPLAIN ANALYZE SELECT count(*) FROM mail_messages
fts-# WHERE to_tsvector('english',body_plain) @@ to_tsquery('aggregate');
                                                                    QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------
 Finalize Aggregate  (cost=122708.56..122708.57 rows=1 width=8) (actual time=26983.786..26
   ->  Gather  (cost=122708.34..122708.55 rows=2 width=8) (actual time=26981.649..26989.39
         Workers Planned: 2
         Workers Launched: 2
         ->  Partial Aggregate  (cost=121708.34..121708.35 rows=1 width=8) (actual time=26
               ->  Parallel Seq Scan on mail_messages  (cost=0.00..121706.49 rows=742 widt
                     Filter: (to_tsvector('english'::regconfig, body_plain) @@ to_tsquery(
                     Rows Removed by Filter: 116770
 Planning Time: 0.258 ms
 JIT:
   Functions: 14
   Options: Inlining false, Optimization false, Expressions true, Deforming true
   Timing: Generation 3.243 ms, Inlining 0.000 ms, Optimization 1.534 ms, Emission 13.796
 Execution Time: 26991.805 ms
```

FTS indexing

```
CREATE INDEX ON mail_messages USING GIN
    (to_tsvector('english',
    subject ||' '|| body_plain));
```

- Since PG12: Generated columns (stored):

```
ALTER TABLE mail_messages
ADD COLUMN fts_col tsvector
GENERATED ALWAYS AS (to_tsvector('english',
    coalesce(subject, '') ||' '||
    coalesce(body_plain, ''))) STORED;

CREATE INDEX ON mail_messages USING GIN (fts_col);
```

FTS, GiST indexed

```
fts=# EXPLAIN ANALYZE SELECT count(*) FROM mail_messages
fts-# WHERE to_tsvector('english',body_plain) @@ to_tsquery('aggregate');
                                                                  QUERY PLAN
-----------------------------------------------------------------------------------------------
 Aggregate  (cost=7210.61..7210.62 rows=1 width=8) (actual time=5630.167..5630.167 rows=1
   ->  Bitmap Heap Scan on mail_messages  (cost=330.46..7206.16 rows=1781 width=0) (actual
         Recheck Cond: (to_tsvector('english'::regconfig, body_plain) @@ to_tsquery('aggre
         Rows Removed by Index Recheck: 4267
         Heap Blocks: exact=7883
         ->  Bitmap Index Scan on mail_messages_to_tsvector_idx  (cost=0.00..330.02 rows=1
               Index Cond: (to_tsvector('english'::regconfig, body_plain) @@ to_tsquery('a
 Planning Time: 0.620 ms
 Execution Time: 5630.249 ms
```

- 26.99 seconds → 5.63 seconds! → ~4.8x faster

FTS, GIN indexed

```
fts=# EXPLAIN ANALYZE SELECT count(*) FROM mail_messages
fts-# WHERE to_tsvector('english',body_plain) @@ to_tsquery('aggregate');
                                                                  QUERY PLAN
-----------------------------------------------------------------------------------------------
 Aggregate  (cost=6873.60..6873.61 rows=1 width=8) (actual time=6.133..6.134 rows=1
   ->  Bitmap Heap Scan on mail_messages  (cost=33.96..6869.18 rows=1769 width=0) (a
         Recheck Cond: (to_tsvector('english'::regconfig, body_plain) @@ to_tsquery(
         Heap Blocks: exact=4630
         ->  Bitmap Index Scan on mail_messages_to_tsvector_idx  (cost=0.00..33.52 r
               Index Cond: (to_tsvector('english'::regconfig, body_plain) @@ to_tsqu
 Planning Time: 0.433 ms
 Execution Time: 5.684 ms
```

- 26.99 seconds → 5.684 **milli**seconds! → **~4700x faster**

Useful modules

- `pg_trgm`
  - Trigram indexing operations
- `unaccent`
  - Dictionary: removes accents / diacritics
- `fuzzystrmatch`
  - String similarity: Levenshtein distances (also Soundex, Metaphone, Double Metaphone)
  - ```
    SELECT name FROM users
    WHERE levenshtein('Stephen', name) <= 2;
    ```
    ```

Free text but not natural?

- One use case: identifying arbitrary strings
  - e.g. keywords in device logs
- Dictionaries not very helpful here
- Arbitrary example: 10M * ~100 char “IoT device” log entries
  - Some contain strings that are significant to user
    (but we don’t know these keywords)
  - Populate table with random hex codes but 1% of log entries contains a keyword from `/etc/dictionaries-common/words`:

    `c4f2cede5da57f0ace6e669b51186cba`**`excruciating`**`9635d8a26aefb2b4ee8b9845e89718577b3266f68dffa5ae12ebfebf1a508b21`

Free text but not natural?

```
fts=# SELECT message FROM logentries LIMIT 5 OFFSET 495;
                                                                 Message
------------------------------------------------------------------------------------------------------------
 da40c1006cd75105c1eb8ea70705828d195b264565f047c6d449e51cf99d01e901cf532f03018e793a394fdac9bb5d2a
 aa88a5c43ec8b2a8578d44f924053e842584c0e6b8295b72230f7d19aa3ba2f2b9e1a4bffcf0f82e4d29344645b714ca
 fe9731c39108a74714cad9fc8570b115howlingb9904fa4ad86544fb778ef5edfe362e02a94c66851c3c8d7fe47b26e5
 b68430decf30085cc2e7810585c5d681source2b638d61c5972f25aa3fa5c35aa2be282f04843cfca007689cc6ecdbe3
 5b7ba17108e416d04788dc9ac15121fad7625fa7c216666bf54c1b0ca21ab618829262dfd67a5cd40aefd66235cf9c7f
(5 rows)

fts=# \dt+ logentries
                        List of relations
 Schema |    Name    | Type  |  Owner   |  Size   | Description
--------+------------+-------+----------+---------+-------------
 public | logentries | table | postgres | 1421 MB |
(1 row)

fts=# SELECT * FROM logentries WHERE message LIKE '%source%';
```

How long?

```
fts=# EXPLAIN ANALYZE SELECT * FROM logentries WHERE message LIKE '%source%'
                                                            QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------------------
 Gather  (cost=1000.00..235029.95 rows=1000 width=109) (actual time=143.010..9654.769 rows=16 loo
   Workers Planned: 2
   Workers Launched: 2
   ->  Parallel Seq Scan on logentries  (cost=0.00..233929.95 rows=417 width=109) (actual time=10
         Filter: (message ~~ '%source%'::text)
         Rows Removed by Filter: 3333594
 Planning Time: 0.220 ms
 JIT:
   Functions: 6
   Options: Inlining false, Optimization false, Expressions true, Deforming true
   Timing: Generation 18.918 ms, Inlining 0.000 ms, Optimization 41.736 ms, Emission 121.955 ms,
 Execution Time: 9673.582 ms
(12 rows)
```

- 9.6 seconds!

Trigrams

- N-gram model: probabilistic language model (Markov Chains)
- 3 characters → trigrams
- Similarity of alphanumeric text is number of shared trigrams

```
CREATE EXTENSION pg_trgm;
SELECT show_trgm('source');
                show_trgm
-----------------------------------------
{" s"," so","ce ",our,rce,sou,urc}
CREATE INDEX ON logentries
USING GIN (message gin_trgm_ops);
```

Other neat trigram tricks

- `similarity(text, text)` → `real`
- `text <-> text` → Distance (1-similarity)
- `text % text` → `true` if over `similarity_threshold`
- Supported by indexes:
  - GIN
  - GiST is efficient: k-nearest neighbour (k-NN)

Did trigrams help?

```
fts=# EXPLAIN ANALYZE SELECT * FROM logentries WHERE message LIKE '%source%';
                                                                  QUERY PLAN
-----------------------------------------------------------------------------------------------------------------------------------------
 Bitmap Heap Scan on logentries  (cost=87.75..3870.45 rows=1000 width=109) (actual time=0.152..0.206 rows
   Recheck Cond: (message ~~ '%source%'::text)
   Rows Removed by Index Recheck: 2
   Heap Blocks: exact=18
   ->  Bitmap Index Scan on logentries_message_idx  (cost=0.00..87.50 rows=1000 width=0) (actual time=0.1
         Index Cond: (message ~~ '%source%'::text)
 Planning Time: 0.222 ms
 Execution Time: 0.258 ms
(8 rows)
```

- 0.258 **milli**seconds! → **~37000x faster**
- Also work with regex

This comes at a cost

```
fts=# \di+ logentries_message_idx
                                    List of relations
 Schema |          Name           | Type  |  Owner   |   Table    |  Size   | Description
--------+-------------------------+-------+----------+------------+---------+-------------
 public | logentries_message_idx | index | postgres | logentries | 1601 MB |
(1 row)
```

Collations

- Sort order and character classification
  - Per-column: `CREATE TABLE test1 (a text COLLATE "de_DE"…`
  - Per-operation: `SELECT a < b COLLATE "de_DE" FROM test1;`
  - Not restricted by `DB LC_COLLATE, LC_CTYPE`
- PG17 has 3 collation providers:
  - `(g)libc` (usually default)
  - `icu` (complex collations, unicode, number sorting)
  - built-in (**new**, limited functionality, fast)

Other types of documents (JSON)

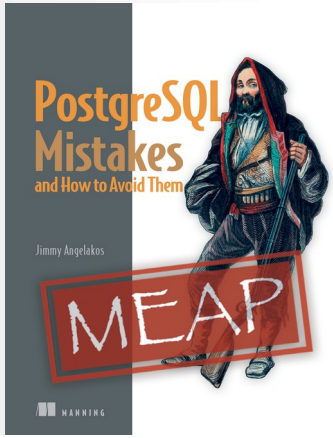
- JSONB supports indexing
  - `(article ->> 'title' ||''|| article ->> 'author')::tsvector`
- `jsonb_to_tsvector()`
  - `SELECT jsonb_to_tsvector('english', <column>, '["numeric","key","string","boolean"]') FROM <table>;`

What else can I use?

- ZomboDB
  - Great name!
  - but still Elasticsearch
- ParadeDB
  - `pg_search` extension (Rust!)
  - Licence: Affero GPL

Thank you ❤️

35% off!
Code: **au35ang**



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