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Postgres® for the AI Generation

From Distance to Intelligence: Evolving Your Vector Search

Bilge Ince & Boriss Mejias

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Time to Rock

Find 11 rock music outfits

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Time to Rock

Find 11 rock music outfits for women

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Time to Rock

Find 11 **rock music outfits** for women

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Time to Rock

Find 11 rock music outfits for **women**

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Time to Rock

Find 11 rock music outfits for women

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LLMs

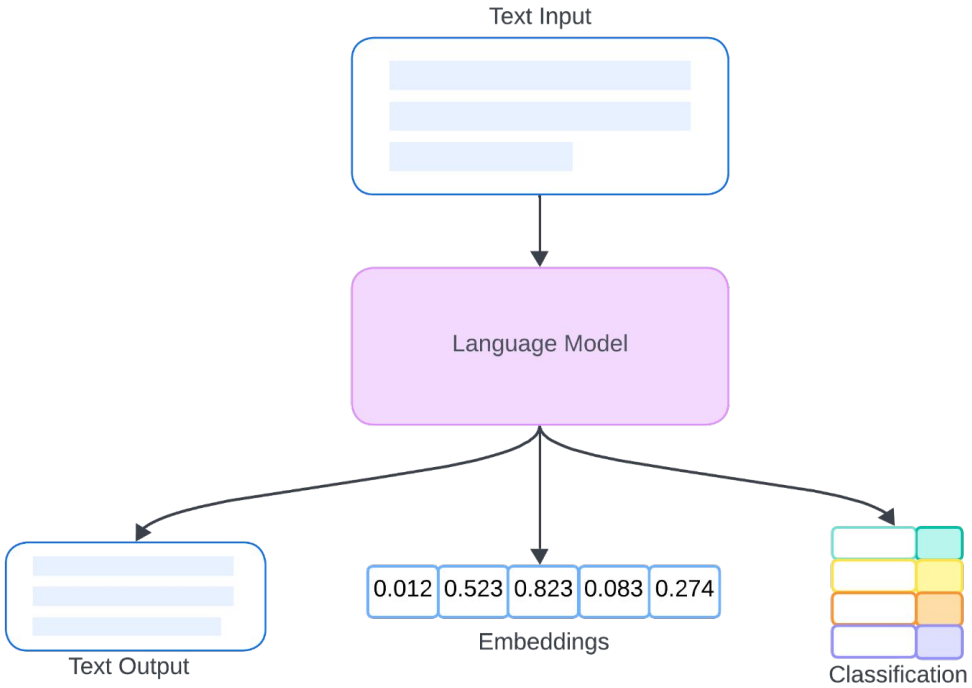

Fig: Hands on LLMs - Jay Alammar & Maarten Grootendorst

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Time to Rock

Search: Rock music outfits

Filter: women

Limit to top 11

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Demo Time

Rock music outfit for women

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The products table

```
CREATE TABLE products (
    id          BIGINT PRIMARY KEY
  , img_id      BIGINT REFERENCES products_images(id)
  , description TEXT
  , gender      TEXT
);
```


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CREATE TABLE products (
    id          BIGINT PRIMARY KEY
  , img_id      BIGINT REFERENCES products_images(id)
  , description TEXT
  , gender      TEXT
);
```

```
CREATE TABLE products_embeddings (
    product_id BIGINT REFERENCES products(id)
  , embedding  vector(384)
);
```


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Time to Rock

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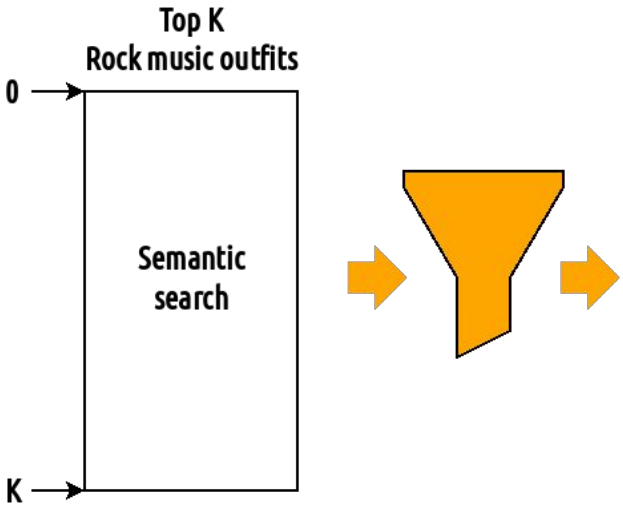

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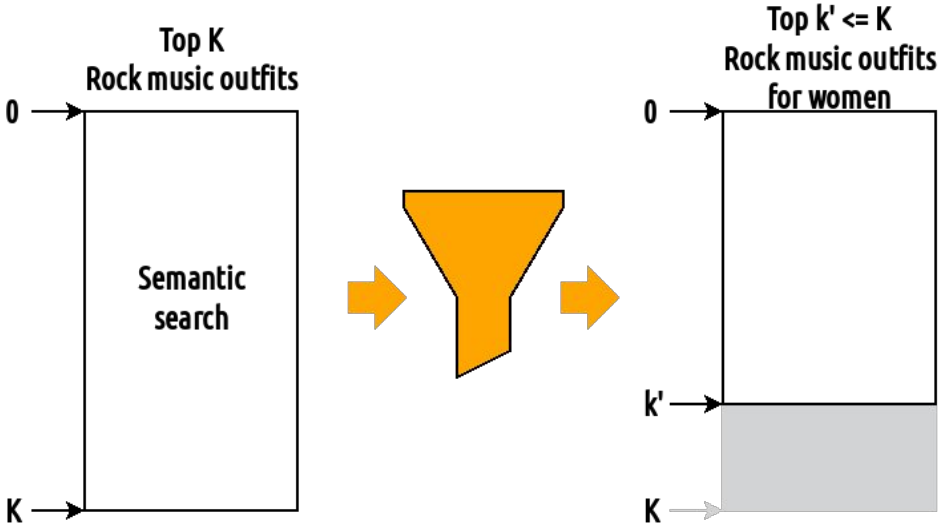

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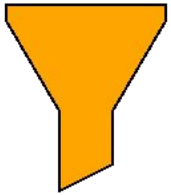

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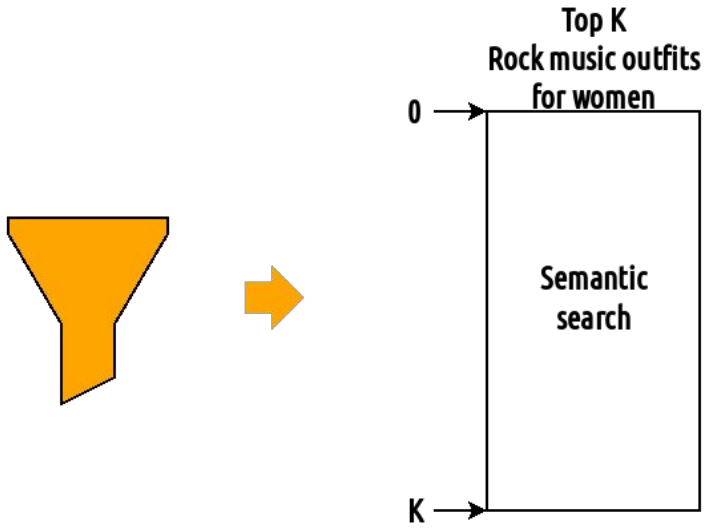

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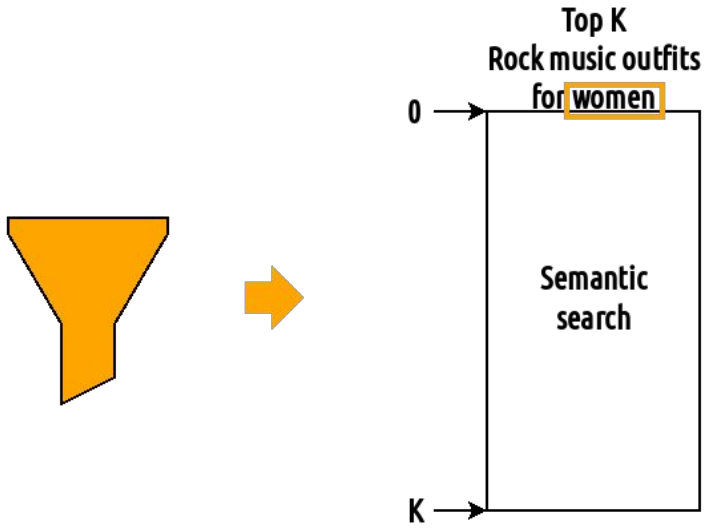

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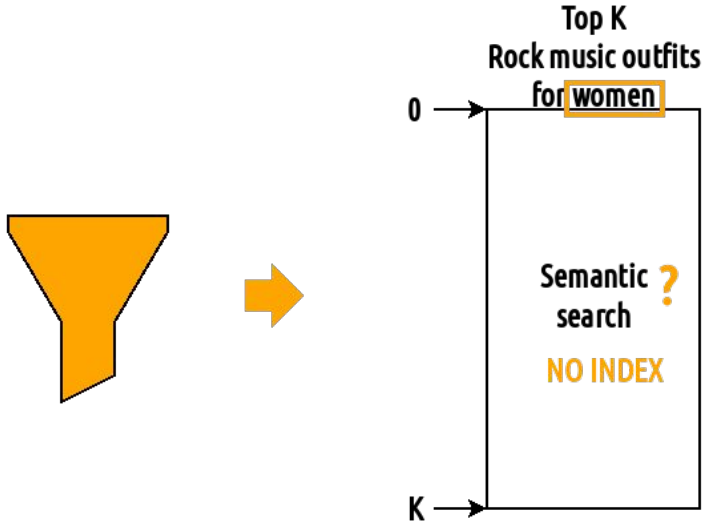
Time to Rock



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Why Getting Search Right Matters

Finding exactly the right product vs. irrelevant suggestions; Slack, Healthcare sector, e-commerce, game

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Demo

Floral Dress for the summer party

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The Promise of Understanding Semantic Meaning

- Finds **related concepts** even without keyword overlap.
- Excellent for **discovery** and **recommendation**.

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The Promise of Understanding Semantic Meaning

- Finds related concepts even without keyword overlap.
- Excellent for discovery and recommendation.
- Handles **synonyms** and related concepts naturally.

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The Promise of Understanding Semantic Meaning

- Finds related concepts even without keyword overlap.
- Excellent for discovery and recommendation.
- Handles synonyms and related concepts naturally.
- Enables **natural language querying** and Question Answering.
- Can search **across modalities** (text-image, text-speech).

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The Reality Behind The Hype

"Nearest" ≠ "Best"

The "Black Box”

Computational Cost

Keyword Blindness

Context Ambiguity

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What can we do?

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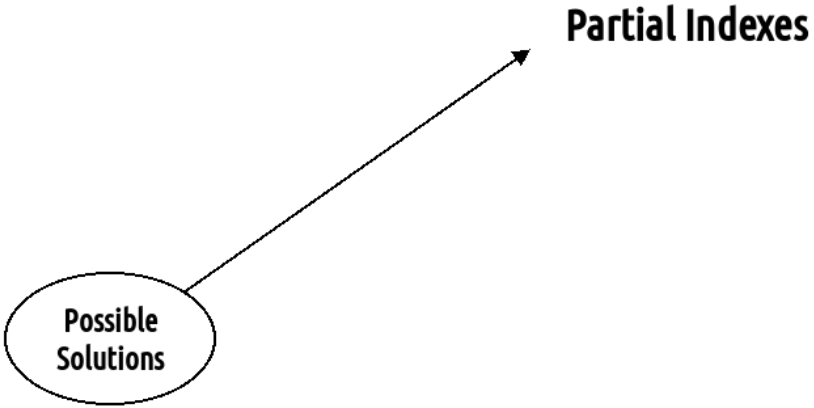
What can we do?



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The products table

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    id          BIGINT PRIMARY KEY
  , img_id      BIGINT REFERENCES products_images(id)
  , description TEXT
  , gender      TEXT
);
```

```
CREATE TABLE products_embeddings (
    product_id BIGINT REFERENCES products(id)
  , embedding  vector(384)
);
```


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```
CREATE TABLE products (
    id          BIGINT PRIMARY KEY
  , img_id      BIGINT REFERENCES products_images(id)
  , description TEXT
  , gender      TEXT
  , embedding   vector(384)
);
```


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The products table

```
CREATE TABLE products (
    id          BIGINT PRIMARY KEY
  , img_id      BIGINT REFERENCES products_images(id)
  , description TEXT
  , gender      TEXT
  , embedding   vector(384)
);
CREATE INDEX ON products USING hnsw (embedding vector_cosine_ops)
WHERE gender = 'women';
```


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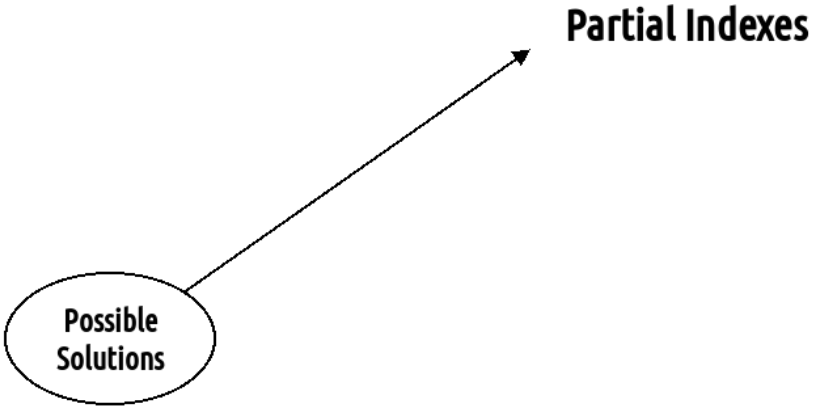

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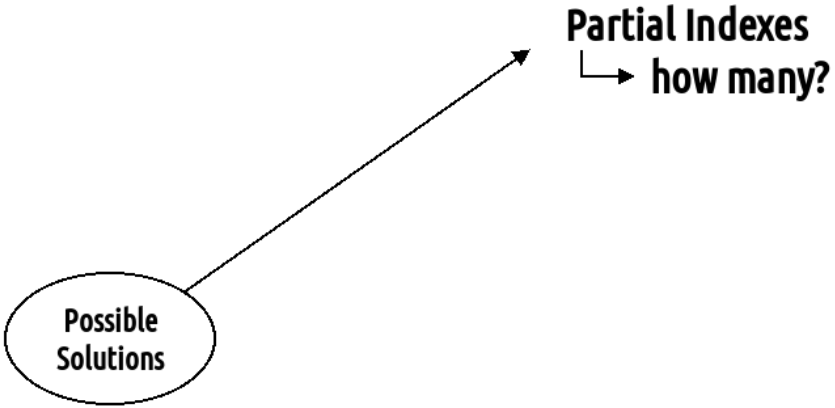

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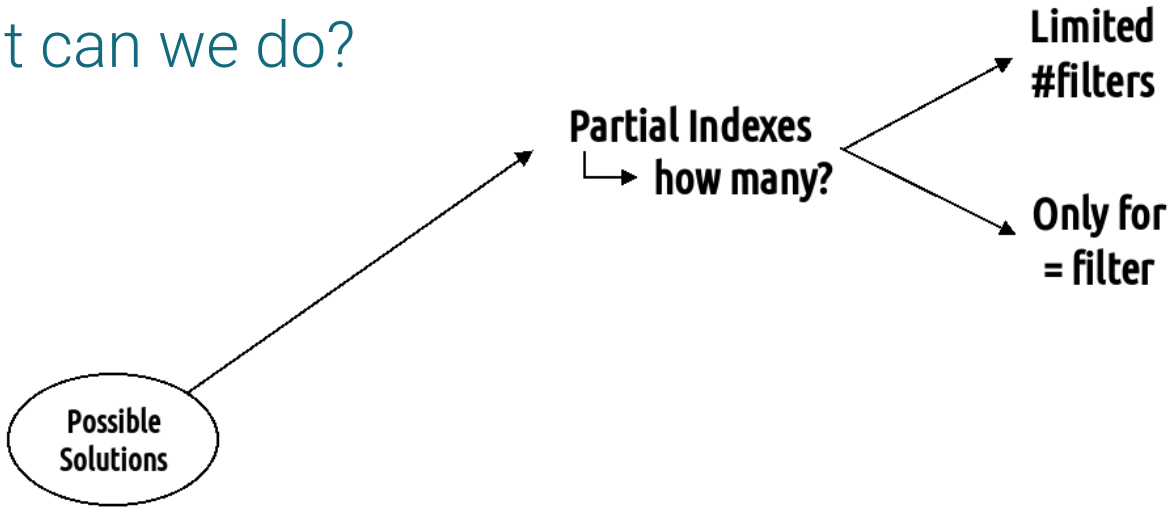

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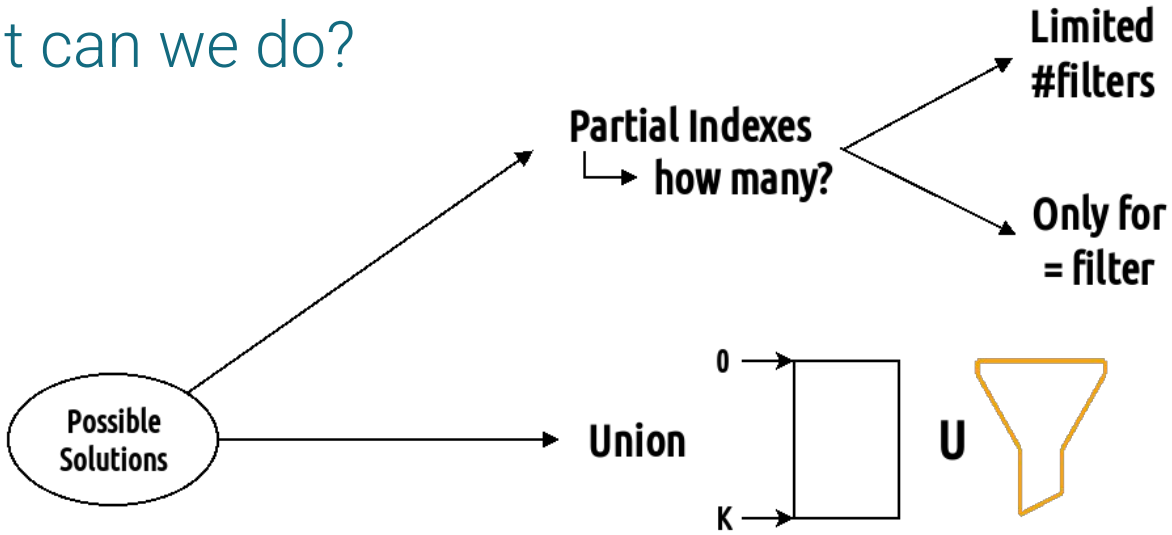

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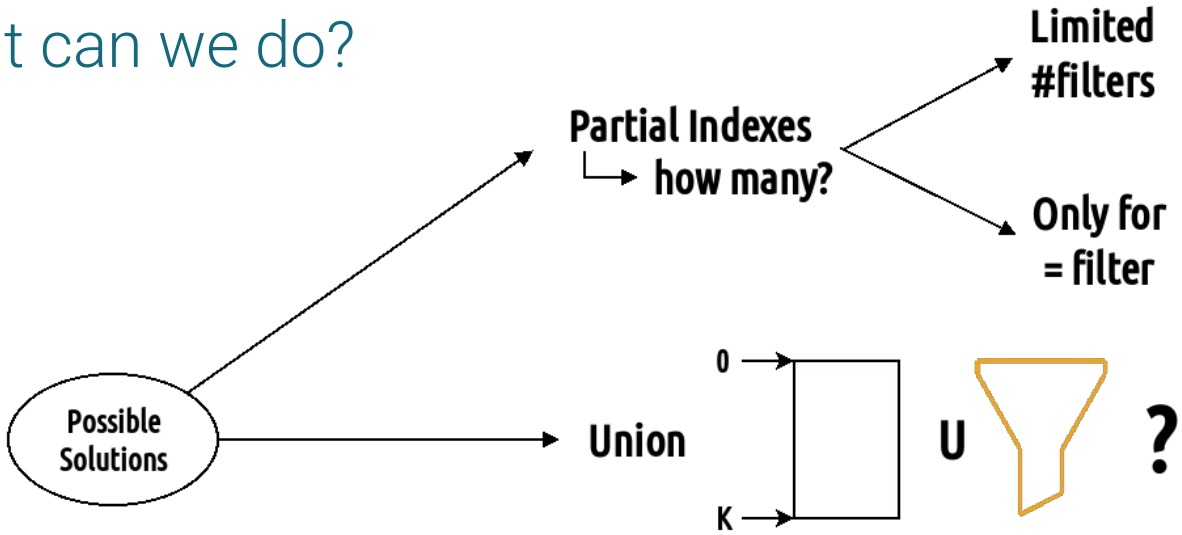
What can we do?



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The Solution: Hybrid Search - Union

- Run Full Text Search and Vector Search queries independently.
- Get two ranked lists of results.
- Combine these lists using an algorithm. Popular option: Reciprocal Rank Fusion

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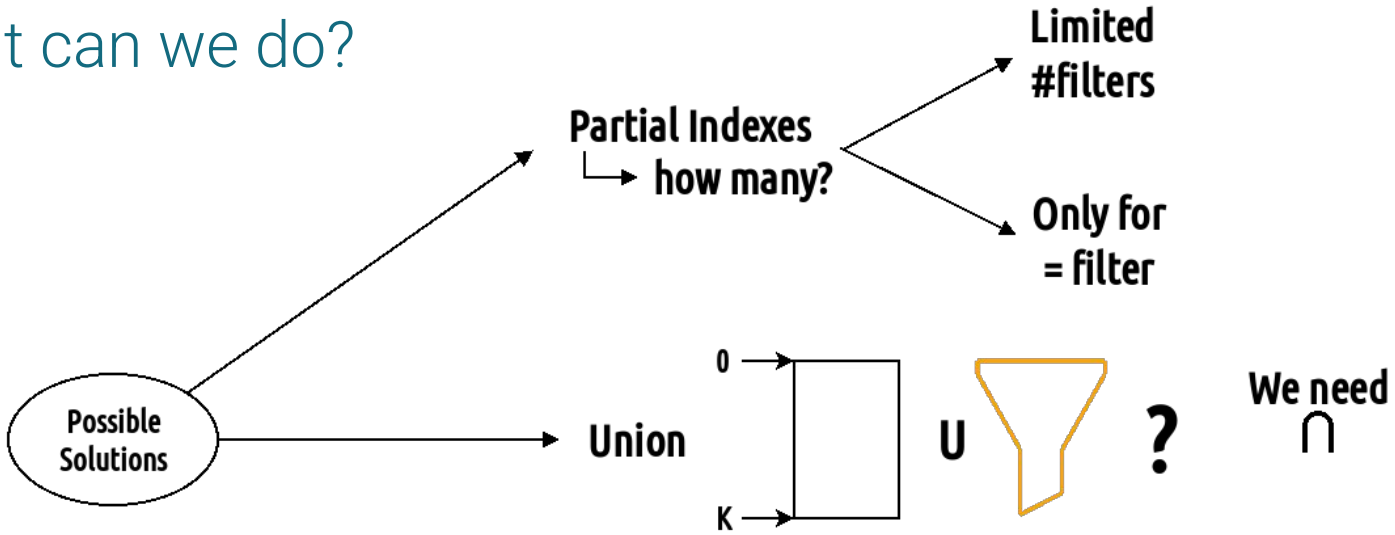
What can we do?



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The Solution: Hybrid Search - Intersect

- Leverage the best of both worlds
- Find semantically relevant items that also satisfy keyword constraints or other filters.

The Method:

Use full text search for essential keywords to get an initial set of candidates (e.g., top 100-500 results).

Then run semantic search on the candidate data for user query that fits with semantic need.

For example; “summer outfit for Thailand trip under €50”

Summer outfit for Thailand - requires semantic search because...

<€50 - is a filtering.

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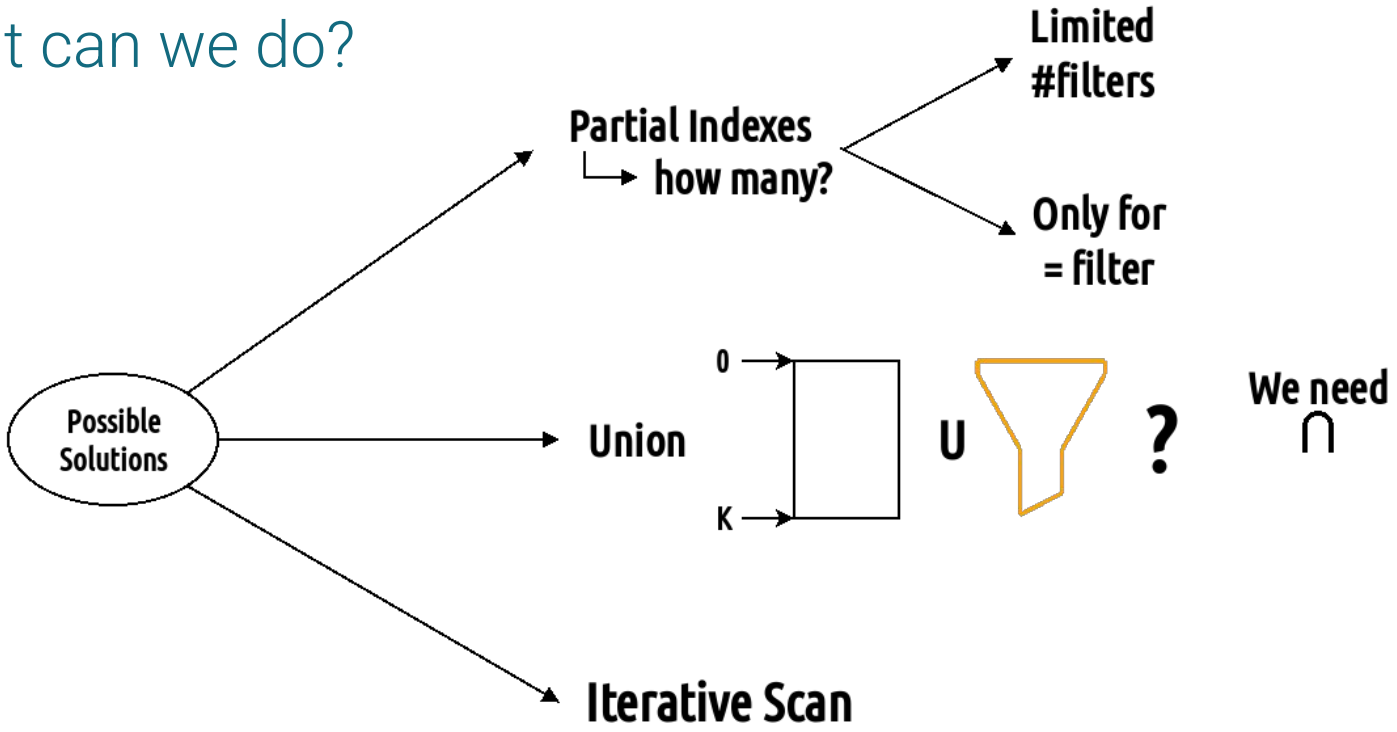
What can we do?



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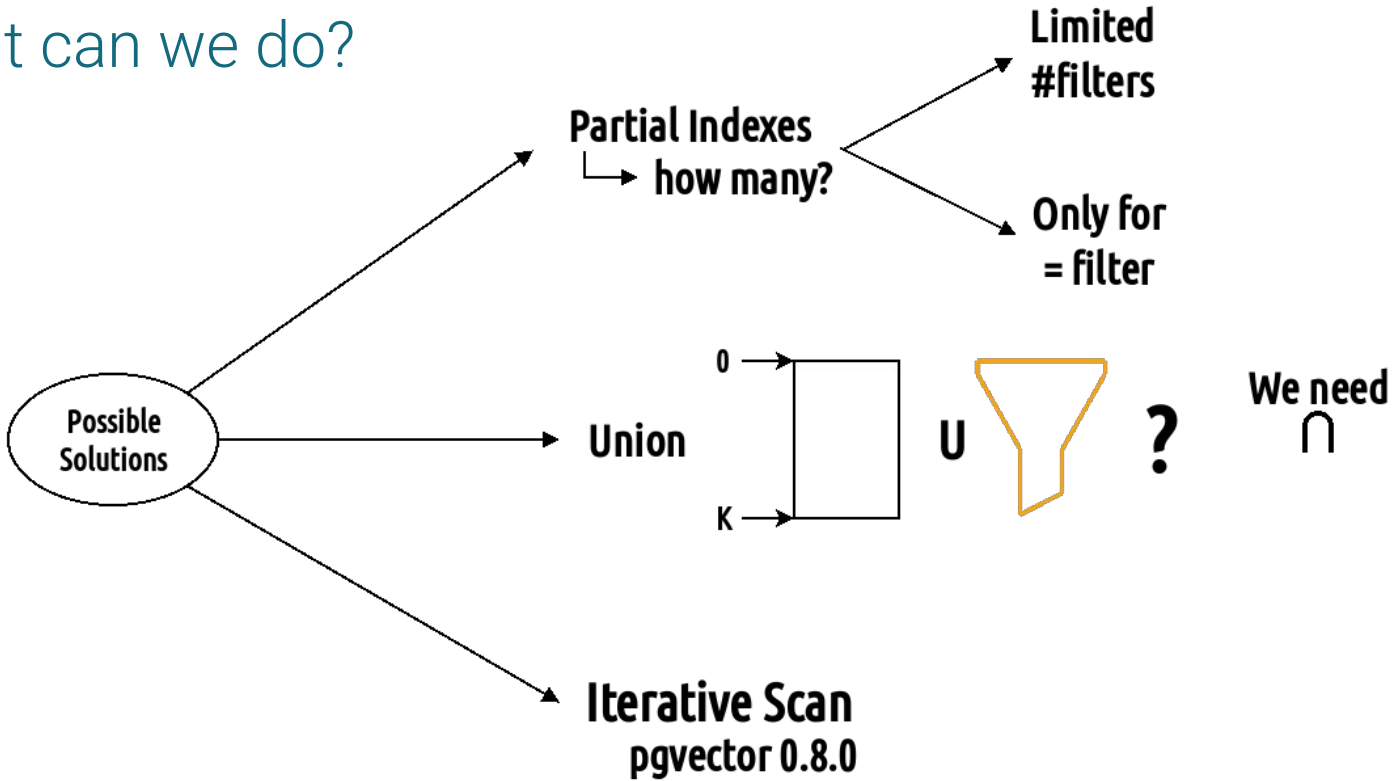
What can we do?



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Hybrid Search: using pgvector

“summer outfit for Thailand trip under €50”

Indexes: HNSW & IVFFlat are Approximate Nearest Neighbor (ANN) indexes.

Standard ANN index scans (especially HNSW in pgvector) often struggle to efficiently apply WHERE clause filters during the nearest neighbor search.

Common Issue: Retrieve Top K vector neighbours -> Then apply metadata filters.
Result: The desired k value didn’t meet as a result, it may not return an output at all.

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Hierarchical Navigable Small Worlds

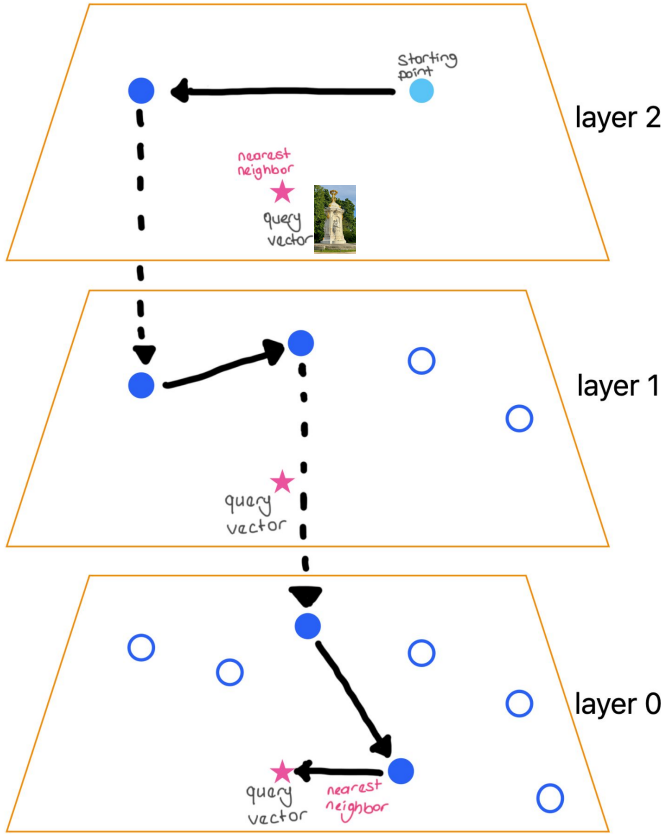
```
CREATE INDEX ON items
USING hnsw (embedding vector_cosine_ops)
WITH (m = 16, ef_construction = 64);
```

```
SET hnsw.ef_search = 100;
```

Hierarchical Navigable Small Worlds

```
CREATE INDEX ON items
USING hnsw (embedding vector_cosine_ops)
WITH (m = 16, ef_construction = 64);
```

```
SET hnsw.ef_search = 100;
```



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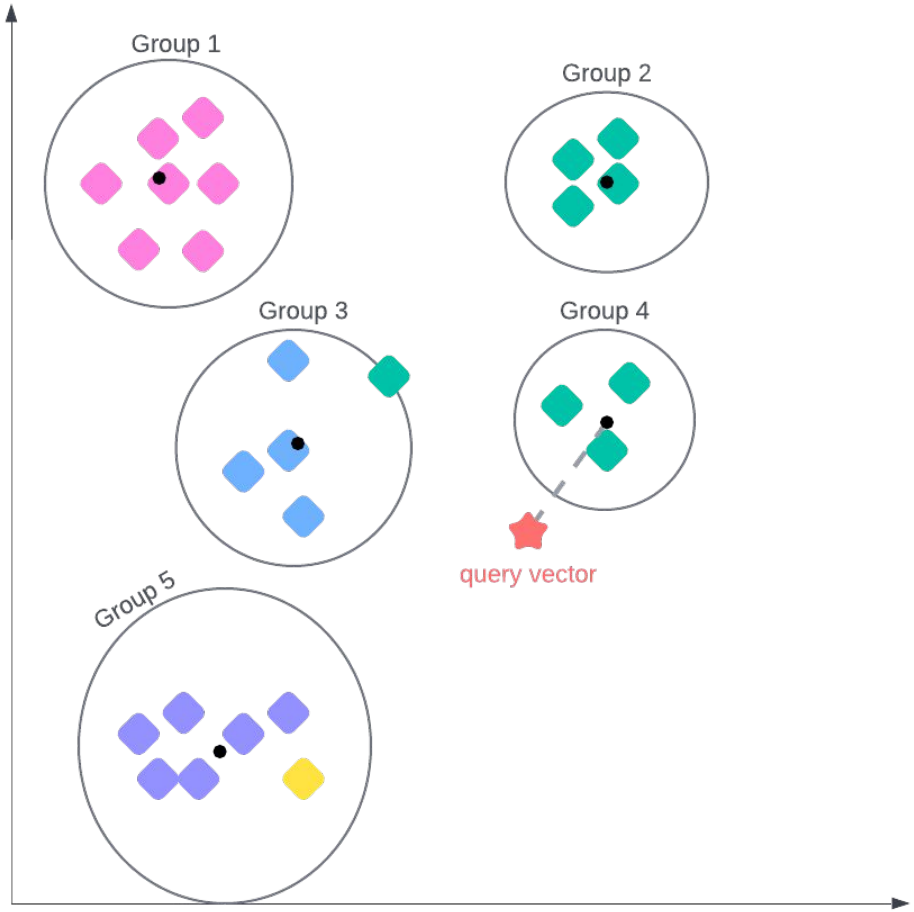
Inverted File Flat

```
CREATE INDEX ON items
USING ivfflat (embedding vector_cosine_ops)
WITH (lists = 1000);

SET ivfflat.probes = 32
```



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Ideal Scenario

```
-- Select top 5 similar image IDs
SELECT
    img_id,
    (embedding <=> '{text_embeddings}') AS score
    -- Calculate similarity score
FROM
    products_embeddings
WHERE
    gender = '{gender}' -- Filter by gender
ORDER BY
    score
LIMIT 11;
```


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The Scenario I can Use ?

```
-- 1. Filter products by gender
WITH filtered_products AS (
    SELECT img_id, productdisplayname
    FROM products_pgconf
    WHERE gender = '{selected_gender}'
)
-- 2. Find top 100 similar embeddings for filtered products
SELECT
    r.img_id, r.score
FROM
    filtered_products fp
CROSS JOIN LATERAL (
    SELECT img_id, (embedding <=> '{text_embeddings}') AS score
    FROM products_embeddings_pgvector
    ORDER BY score
    LIMIT 100
) AS r
-- 3. Join and get the top 5 most similar
WHERE r.img_id = fp.img_id
ORDER BY r.score LIMIT 11;
```


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The Scenario I can Use ?

```
-- 1. Filter products by gender
WITH filtered_products AS (
    SELECT img_id, productdisplayname
    FROM products_pgconf
    WHERE gender = '{selected_gender}'
)
-- 2. Find top 100 similar embeddings for filtered products
SELECT
    r.img_id, r.score
FROM
    filtered_products fp
CROSS JOIN LATERAL (
    SELECT img_id, (embedding <=> '{text_embeddings}') AS score
    FROM products_embeddings_pgvector
    ORDER BY score
    LIMIT 100
) AS r
-- 3. Join and get the top 5 most similar
WHERE r.img_id = fp.img_id
ORDER BY r.score LIMIT 11;
```


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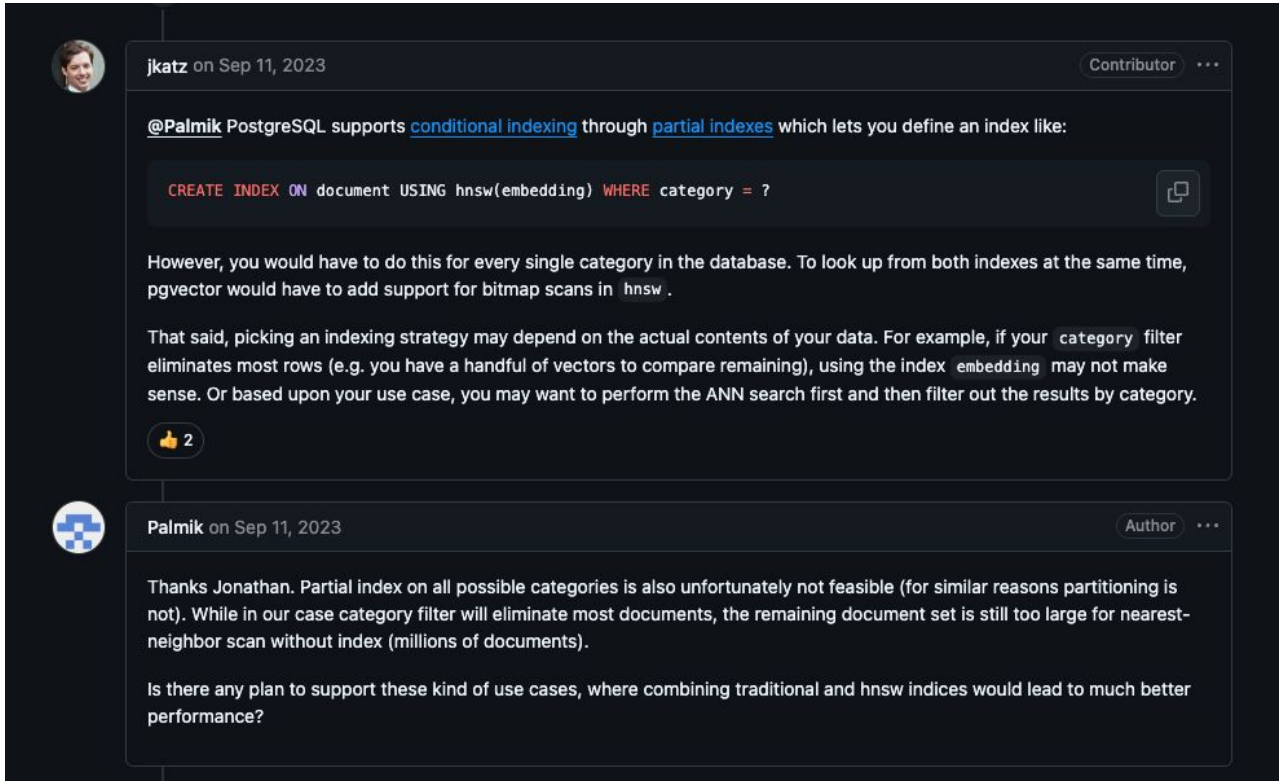
Hybrid Search with Intersection: using pgvector



jkatz on Sep 11, 2023 — Contributor

@Palmik PostgreSQL supports conditional indexing through partial indexes which lets you define an index like:

```
CREATE INDEX ON document USING hnsw(embedding) WHERE category = ?
```

However, you would have to do this for every single category in the database. To look up from both indexes at the same time, pgvector would have to add support for bitmap scans in `hnsw`.

That said, picking an indexing strategy may depend on the actual contents of your data. For example, if your `category` filter eliminates most rows (e.g. you have a handful of vectors to compare remaining), using the index `embedding` may not make sense. Or based upon your use case, you may want to perform the ANN search first and then filter out the results by category.

👍 2

Palmik on Sep 11, 2023 — Author

Thanks Jonathan. Partial index on all possible categories is also unfortunately not feasible (for similar reasons partitioning is not). While in our case category filter will eliminate most documents, the remaining document set is still too large for nearest-neighbor scan without index (millions of documents).

Is there any plan to support these kind of use cases, where combining traditional and hnsw indices would lead to much better performance?

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Hybrid Search: using pgvector v0.8.0

Iterative Index Scans

With approximate indexes, queries with filtering can return less results since filtering is applied *after* the index is scanned. Starting with 0.8.0, you can enable iterative index scans, which will automatically scan more of the index until enough results are found (or it reaches `hnsw.max_scan_tuples` or `ivfflat.max_probes`).

Iterative scans can use strict or relaxed ordering.

Strict ensures results are in the exact order by distance

```
SET hnsw.iterative_scan = strict_order;
```

Relaxed allows results to be slightly out of order by distance, but provides better recall

```
SET hnsw.iterative_scan = relaxed_order;
# or
SET ivfflat.iterative_scan = relaxed_order;
```

With relaxed ordering, you can use a materialized CTE to get strict ordering

```
WITH relaxed_results AS MATERIALIZED (
    SELECT id, embedding <-> '[1,2,3]' AS distance FROM items WHERE category_id = 123 ORDER BY
) SELECT * FROM relaxed_results ORDER BY distance;
```

For queries that filter by distance, use a materialized CTE and place the distance filter outside of it for best performance (due to the current behavior of the Postgres executor)

```
WITH nearest_results AS MATERIALIZED (
    SELECT id, embedding <-> '[1,2,3]' AS distance FROM items ORDER BY distance LIMIT 5
) SELECT * FROM nearest_results WHERE distance < 5 ORDER BY distance;
```


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VectorChord Vchord+Vchord_BM25

- VectorChord-BM25 is a PostgreSQL extension for keyword search. It not only implements BM25 ranking but also includes a tokenizer and a Block-WeakAnd index to improve speed.
- Semantic Search is utilizing RabitQ algorithm.
  - RabitQ is a quantization algorithm for high-dimensional spaces, designed to improve the storage and retrieval efficiency of high-dimensional data, such as embedded vectors.

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Iterative Scan

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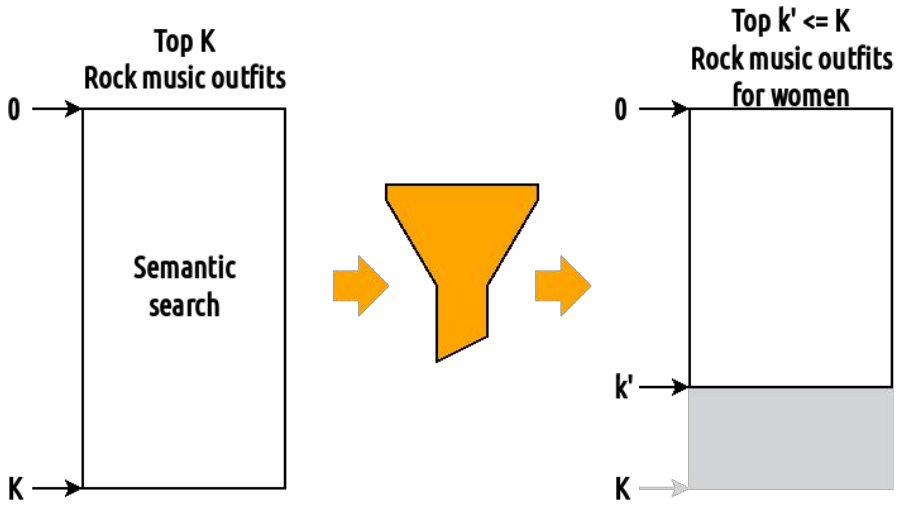
Iterative Scan



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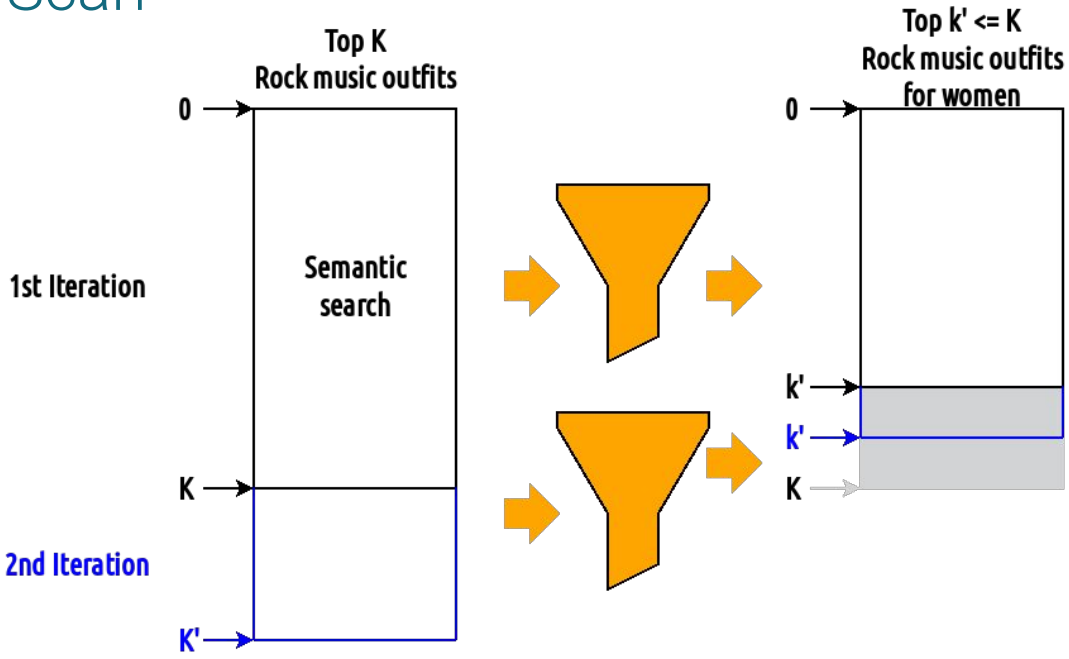
Iterative Scan



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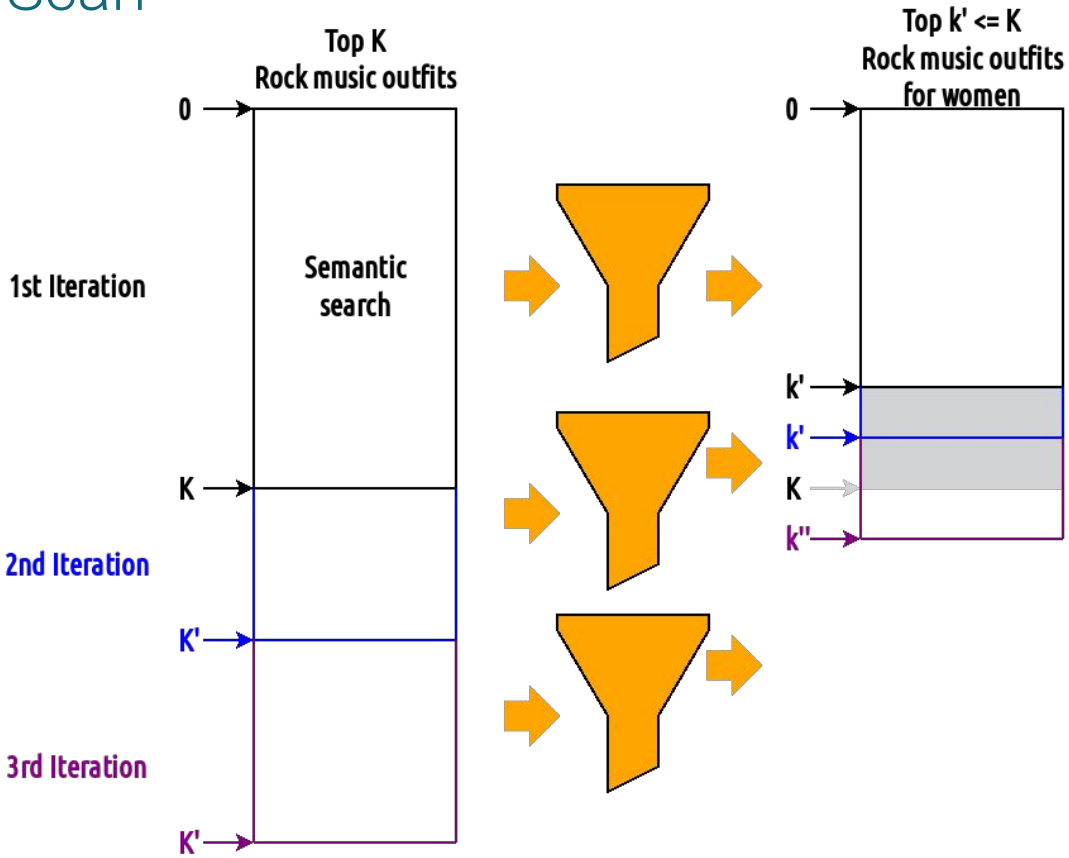
Iterative Scan



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Closing words

- Full text is not enough
- Vector search is not enough
- Existing tools only solves part of the problem or too expensive (and complicated)
- Iterative scans looks promising yet not cost-efficient

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References

1. Hands on LLMs - Jay Alammar & Maarten Grootendorst
2. https://github.com/pgvector/pgvector/issues/259
3. https://github.com/pgvector/pgvector?tab=readme-ov-file#iterative-index-scans
4. https://github.com/pgvector/pgvector/issues/301
5. https://blog.vectorchord.ai/hybrid-search-with-postgres-native-bm25-and-vectorchord

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Any Questions?

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