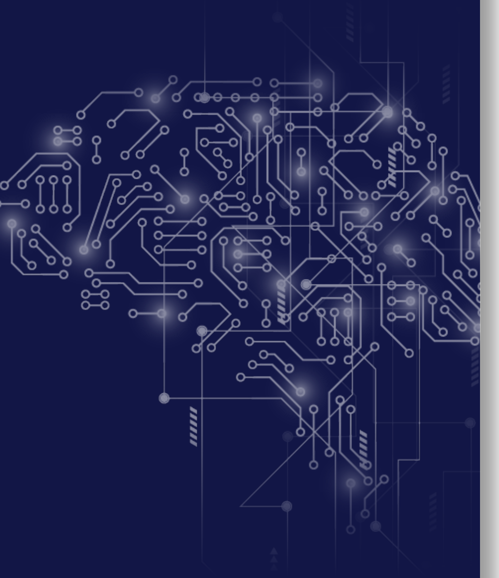


# Bringing vectors to POSTGRES

P2D2 2024, Prague Czech Republic

Gülçin YILDIRIM JELINEK
Staff Engineer, EDB

# Gülçin Yıldırım Jelínek

## Staff Engineer, EDB

Host The Builders: A Postgres Podcast

Co-founder Prague PostgreSQL Meetup

Previously on Board of Directors PostgreSQL Europe

X: @apatheticmagpie, @postgrespodcast, @PrahaPostgreSQL

EDB

# Agenda

1. What is pgvector?
2. What is vector search and why is it used?
3. Generating and querying embeddings
4. New index types: IVFFlat and HNSW
5. Future of vectors, AI and Postgres

EDB

# pgvector

Open-source Postgres extension for vector similarity search

EDB

# Language Support

- Go: pgvector-go
- Python: pgvector-python
- Rust: pgvector-rust
- C: pgvector-c
- JavaScript, TypeScript: pgvector-node
- PHP: pgvector-php

# What is vector (similarity) search?

**Vector similarity search** is a technique used to find **the most similar vectors** to a **given vector** (usually a **query vector**).

This query is typically performed by calculating distances in vector space, and various **metrics** (such as **Euclidean distance, cosine similarity**) can be used to measure the similarity between the query vector and other vectors.

# What is vector (similarity) search?

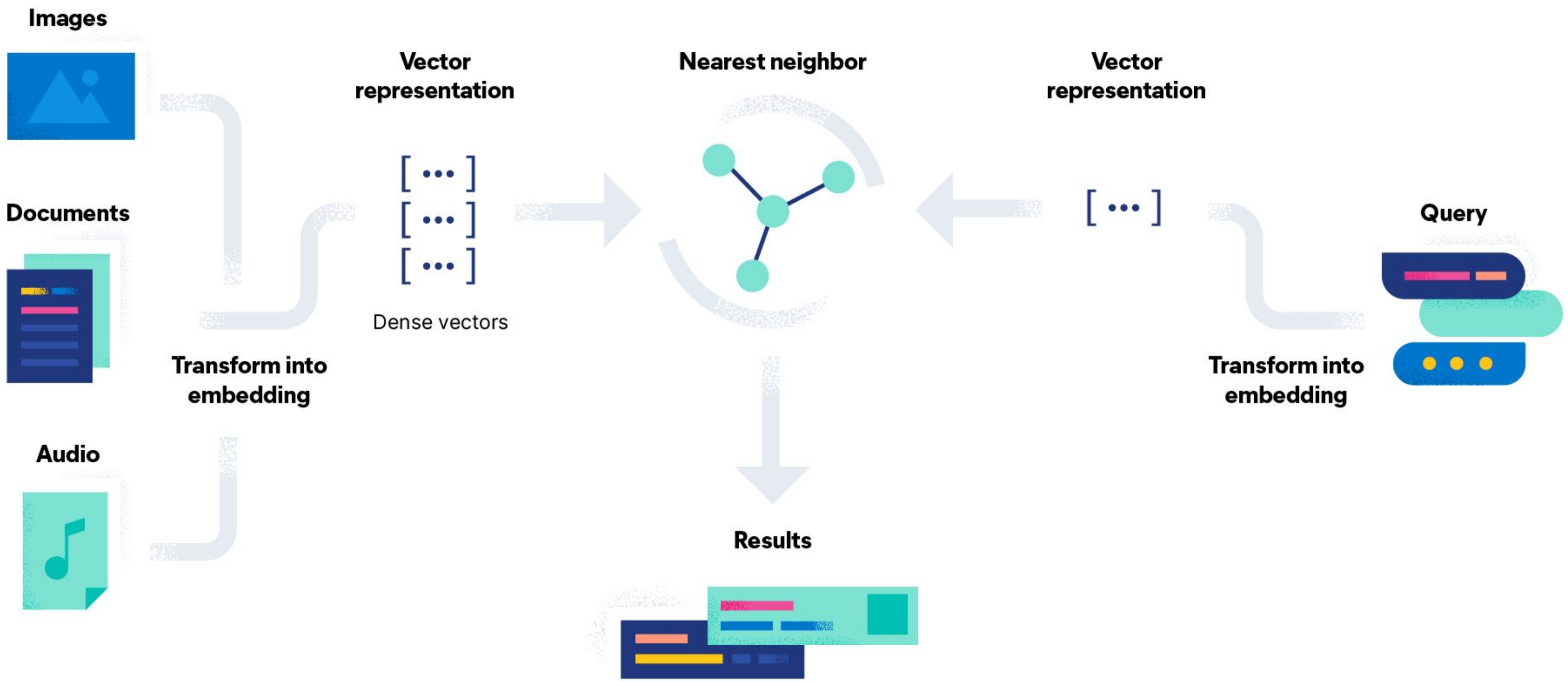
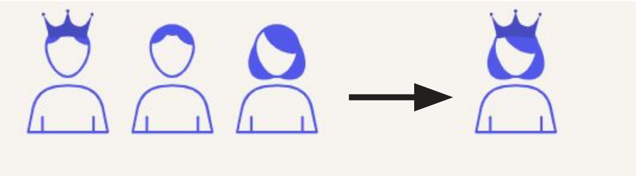



*Image source: https://www.elastic.co/what-is/vector-search*

# What is vector (similarity) search?

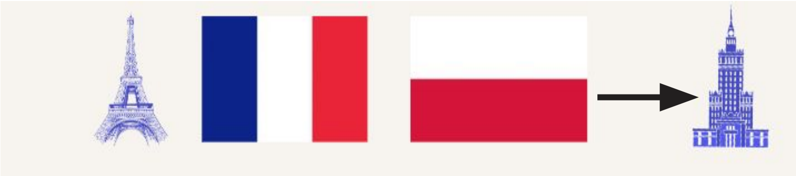
**queen**

king - man + woman



**warsaw**

paris - france + poland



# What is vector search useful for?

**AI applications**: working with **high-dimensional** data

- Recommendation engines
- Image search
- Natural language processing (NLP)
- Content-based filtering
- Similarity-based AI tasks
- Prediction solutions

# What is vector?

$X = [1, 3, 5]$

# What is vector?

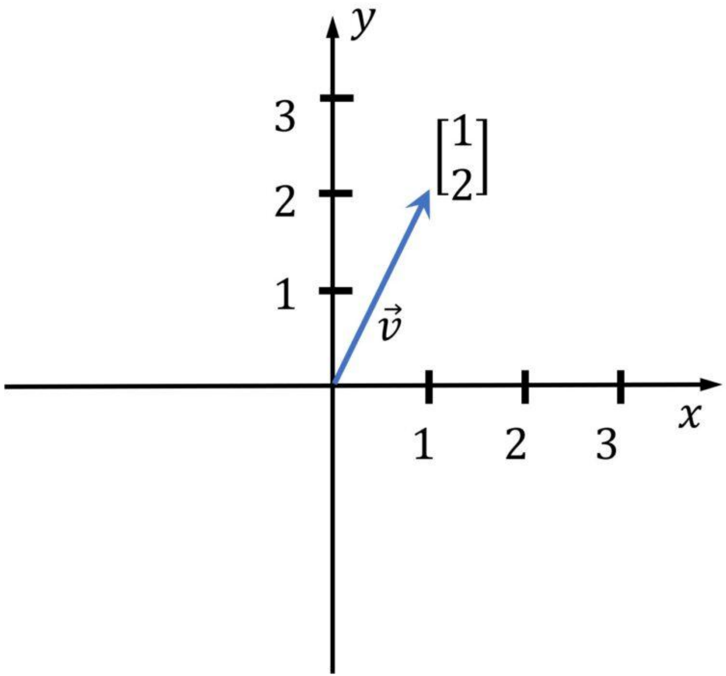



*Image source: https://media5.datahacker.rs/2020/03/Picture36-1-768x712.jpg*

# Vector Data Type

Each vector takes **4 * dimensions + 8 bytes** of storage

Vectors can have up to 16,000 dimensions.

## Vector operators

- <-> Euclidean distance
- <#> negative inner product
- <=> cosine distance
- + element-wise addition
- - element-wise subtraction
- * element-wise multiplication

## Vector functions

- cosine_distance
- inner_product
- l2_distance (Euclidean distance)
- l1_distance
- vector_dims (number of dimensions)
- vector_norm

# Sample app code

https://github.com/gulcin/pgvector_blog

```sql
postgres=# Create extension vector;
CREATE EXTENSION

CREATE TABLE documents (
     id int PRIMARY KEY,
     title text NOT NULL,
     content TEXT NOT NULL
);
```

```sql
-- Create document_embeddings table
CREATE TABLE document_embeddings (
    id int PRIMARY KEY,
    embedding vector(1536) NOT NULL
);
```

```sql
CREATE INDEX document_embeddings_embedding_idx ON document_embeddings USING hnsw (embedding
vector_l2_ops);
```

```sql
-- Insert documents into documents table
INSERT INTO documents VALUES ('1', 'pgvector', 'pgvector is a PostgreSQL extension that provides
support for vector similarity search and nearest neighbor search in SQL.');
INSERT INTO documents VALUES ('2', 'pg_similarity', 'pg_similarity is a PostgreSQL extension that
provides similarity and distance operators for vector columns.');
INSERT INTO documents VALUES ('3', 'pg_trgm', 'pg_trgm is a PostgreSQL extension that provides
functions and operators for determining the similarity of alphanumeric text based on trigram
matching.');
INSERT INTO documents VALUES ('4', 'pg_prewarm', 'pg_prewarm is a PostgreSQL extension that provides
functions for prewarming relation data into the PostgreSQL buffer cache.');
```

# What are embeddings and how do we generate them?

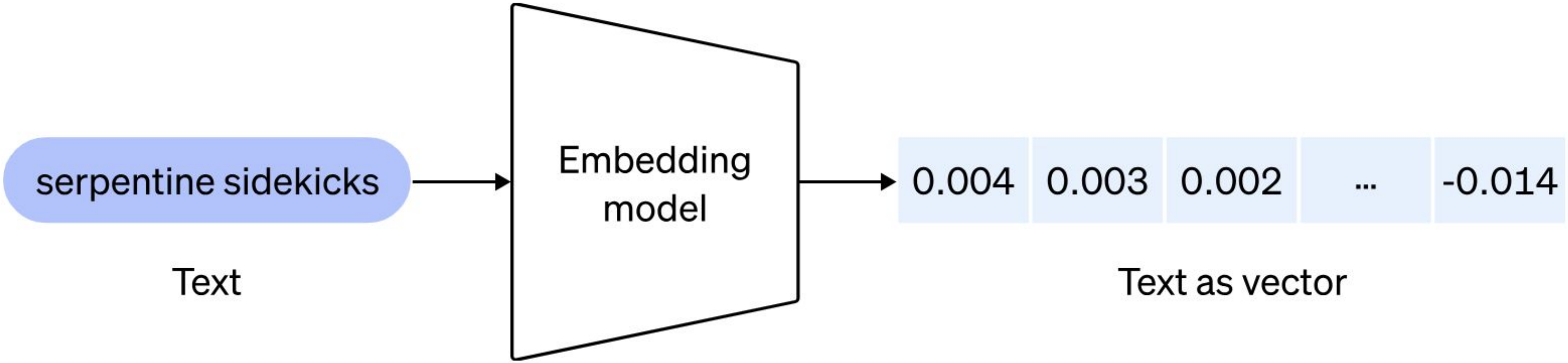
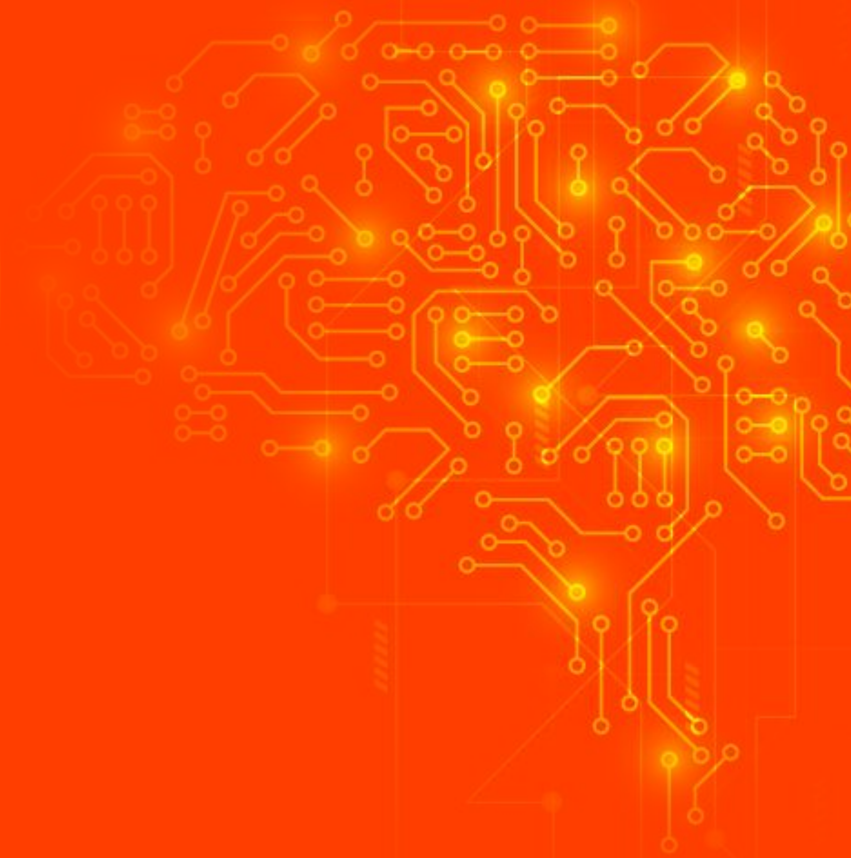



*Image source: https://cdn.openai.com/new-and-improved-embedding-model/draft-20221214a/vectors-1.svg*

```python
# Python code to preprocess and embed documents
import openai
import psycopg2

# Load OpenAI API key
openai.api_key = "sk-..." #YOUR OWN API KEY

# Pick the embedding model
model_id = "text-embedding-ada-002"

# Connect to PostgreSQL database
conn = psycopg2.connect(database="postgres", user="gulcin.jelinek", host="localhost", port="5432")

# Fetch documents from the database
cur = conn.cursor()
cur.execute("SELECT id, content FROM documents")
documents = cur.fetchall()

# Process and store embeddings in the database
for doc_id, doc_content in documents:
    embedding = openai.Embedding.create(input=doc_content, model=model_id)['data'][0]['embedding']
    cur.execute("INSERT INTO document_embeddings (id, embedding) VALUES (%s, %s);", (doc_id,
embedding))
    conn.commit()

# Commit and close the database connection
conn.commit()
```

# Querying Embeddings



```python
# Python code to preprocess and embed documents
import psycopg2

# Connect to PostgreSQL database
conn = psycopg2.connect(database="postgres", user="gulcin.jelinek", host="localhost", port="5432")

cur = conn.cursor()
# Fetch extensions that are similar to pgvector based on their descriptions
query = """
WITH pgv AS (
    SELECT embedding
      FROM document_embeddings JOIN documents USING (id)
     WHERE title = 'pgvector'
)
SELECT title, content
  FROM document_embeddings
  JOIN documents USING (id)
 WHERE embedding <-> (SELECT embedding FROM pgv) < 0.5;"""
cur.execute(query)

# Fetch results
results = cur.fetchall()

# Print results in a nice format
for doc_title, doc_content in results:
    print(f"Document title: {doc_title}")
    print(f"Document text: {doc_content}")
    print()
```

# Results

```
❯ python3 query.py
Document title: pgvector
Document text: pgvector is a PostgreSQL extension that provides support for vector similarity search
and nearest neighbor search in SQL.

Document title: pg_similarity
Document text: pg_similarity is a PostgreSQL extension that provides similarity and distance
operators for vector columns.
```

Accuracy

Precision

Recall

# Indexing

- pgvector performs “exact nearest neighbor search” by default
- Add index to use “approximate nearest neighbor search”
- Supported index types:
  - IVFFlat
  - HNSW (added with 0.5.0)

EDB

# Index Types

## IVFFLAT

- Divides vectors into **lists**
- **Faster build** times
- Uses **less memory**
- **Lower query performance** (speed-recall tradeoff)
- Create index **after the table has some data**

## HNSW

- Creates a **multilayer graph**
- **Slower build** times
- Uses **more memory**
- **Better query performance**
- Index can be created **without any data in the table** (no training step)

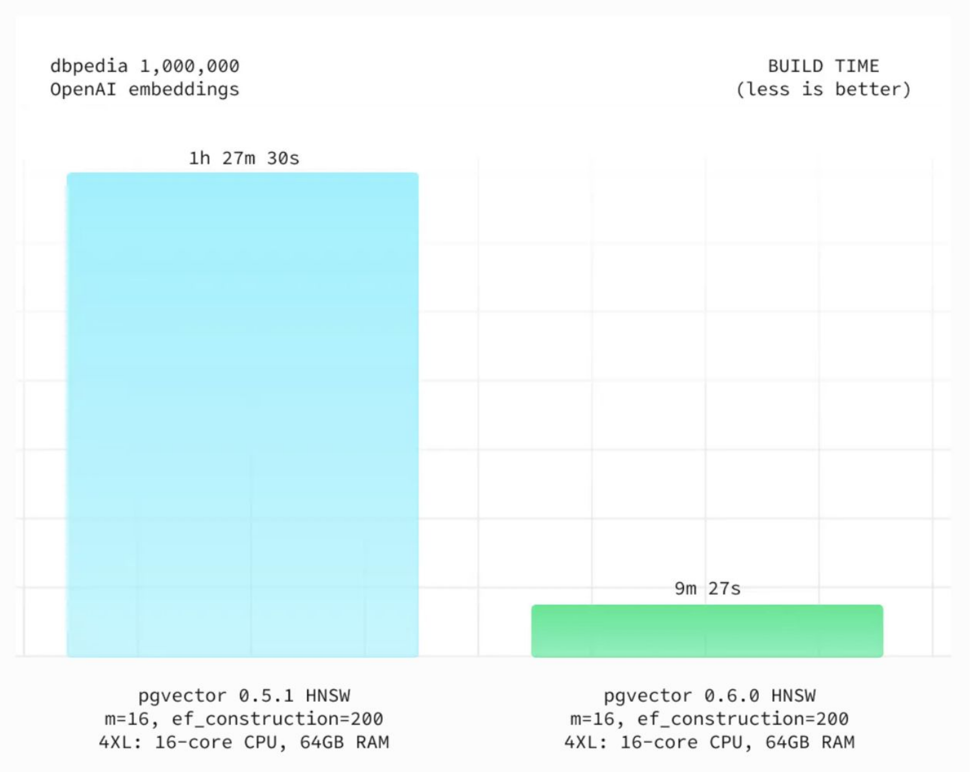



*Image source: https://supabase.com/blog/pgvector-fast-builds*

# Future of vectors and Postgres

- **pgvector 0.7.0 (unreleased)**
  - Add **halfvec** and **sparsevec** type
  - Support for **bit vectors** to HNSW
  - Add hamming_distance function and jaccard_distance function
  - Add **quantize_binary** function and **subvector** function
  - Updated comparison operators to support vectors with different dimensions
- **pgvector 0.6.0 (29 Jan 2024)**
  - Support for **parallel index builds** for HNSW
  - Improved performance of HNSW
  - Reduced memory usage and reduced WAL generation for HNSW index builds

EDB

EDB

# Děkuji! Thank you!

Gülçin Yıldırım Jelínek
gulcin.yildirim-jelinek@enterprisedb.com