

# Vector Database for Semantic Similarity

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## What is Qdrant?

**Qdrant** is a vector similarity search engine that allows you to find similar items based on their **meaning**, not just exact keyword matches.

### Real-World Example:

Query: "Contract was breached due to late delivery"

Keyword Search (Traditional):

✗ Matches only cases with exact words "contract", "breached", "late", "delivery"

Semantic Search (Qdrant):

☑ Also finds:

- "Agreement was violated because of delayed shipment"
- "Party failed to deliver goods on time as promised"
- "Contractual obligations not met due to timing issues"

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## How It Works

### 1. Text → Vector Conversion

Text: "Plaintiff argues breach of contract..."

↓ (Embedding Model)

Vector: [0.234, -0.891, 0.456, ..., 0.123] # 384 dimensions

### 2. Similarity Calculation

Uses **cosine similarity** to find vectors pointing in similar directions:

Case A Vector: →

Case B Vector: ↗ (Similar: 0.89 score)

Case C Vector: ✓ (Different: 0.12 score)

### 3. Fast Search

Qdrant uses **HNSW** (Hierarchical Navigable Small World) algorithm:

- Search millions of vectors in milliseconds

- Finds approximate nearest neighbors efficiently

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## 🧠 Use Cases for AI Judge

### 1. Find Similar Cases

```
# When creating a new case, find similar historical cases
similar = vector_db.find_similar_cases(
    query_text="Breach of software development contract",
    limit=5,
    min_score=0.7 # 70% similarity threshold
)

# Returns:
[
    {"case_id": "case-123", "similarity": 0.92, "verdict": "..."},
    {"case_id": "case-456", "similarity": 0.87, "verdict": "..."},
    ...
]
```

### 2. Find Similar Arguments

```
# Find what similar arguments were used in past cases
similar_args = vector_db.find_similar_arguments(
    query_text="Force majeure clause applies due to pandemic",
    side="B", # Only defense arguments
    limit=10
)
```

### 3. Pattern Discovery

```
# What arguments typically win for plaintiffs?
patterns = vector_db.find_winning_patterns(
    winning_side="A",
    limit=20
)
```

### 4. Smart Recommendations

```
# Get comprehensive insights for a case
recommendations = vector_db.get_case_recommendations(
    case_id="new-case",
    side_a_text="...",

```

```

    side_b_text="...",
    limit=5
)

# Returns:
{
    "similar_cases": [...],
    "similar_arguments": {
        "side_a": [...],
        "side_b": [...]
    },
    "recommendations": [
        "Found 3 similar cases where Side A won",
        "Side B's force majeure argument has 78% success rate"
    ]
}

```

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## Technical Details

### Embedding Model

**Model:** `all-MiniLM-L6-v2`

- **Size:** 22MB (lightweight!)
- **Dimensions:** 384
- **Speed:** ~1000 sentences/sec on CPU
- **Accuracy:** 85%+ on semantic similarity tasks
- **Language:** English (primary), 50+ languages supported

### Why This Model?

1. **Fast:** Runs on CPU, no GPU needed
2. **Small:** Easy to deploy
3. **Accurate:** Good balance of speed vs accuracy
4. **Proven:** Used by thousands of projects

### Alternatives (if you want to upgrade):

- `all-mpnet-base-v2` (768 dim, more accurate, slower)
- `multilingual-e5-base` (768 dim, better multilingual)
- `bge-large-en-v1.5` (1024 dim, state-of-the-art)

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## Setup & Configuration

### Option 1: In-Memory (Development)

```
# backend/.env
QDRANT_URL=:memory:
```

☑ **Pros:** No installation needed, instant start

✗ **Cons:** Data lost on restart

## Option 2: Docker (Local Production)

```
docker run -p 6333:6333 -p 6334:6334 \
-v $(pwd)/qdrant_storage:/qdrant/storage \
qdrant/qdrant
```

```
# backend/.env
QDRANT_URL=http://localhost:6333
```

☑ **Pros:** Persistent, fast, free

✗ **Cons:** Need Docker

## Option 3: Qdrant Cloud (Production)

```
# Sign up at https://qdrant.to/cloud
# Free tier: 1GB storage, 1M vectors
```

```
# backend/.env
QDRANT_URL=https://xxxxx.aws.cloud.qdrant.io
QDRANT_API_KEY=your_api_key_here
```

☑ **Pros:** Managed, scalable, reliable

✗ **Cons:** \$0-25/month



## API Endpoints (Vector Search)

### Find Similar Cases

```
POST /api/case/similar-search
{
  "query": "Software development contract breach",
  "limit": 5,
  "min_score": 0.7
}
```

```
}

Response:
{
  "similar_cases": [
    {
      "case_id": "case-123",
      "similarity_score": 0.89,
      "side_a_preview": "...",
      "side_b_preview": "...",
      "verdict_preview": "..."
    }
  ]
}
```

## Get Recommendations

```
GET /api/case/{case_id}/recommendations

Response:
{
  "similar_cases": [...],
  "similar_arguments": {...},
  "recommendations": [...]
}
```

## Search Arguments

```
POST /api/arguments/search
{
  "query": "Force majeure pandemic delay",
  "side": "B",
  "limit": 10
}
```

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## Advanced Features

### 1. Hybrid Search (Coming Soon)

Combine keyword + semantic search:

```
# Find cases matching "contract" AND semantically similar to query
results = hybrid_search(
    keywords=["contract", "breach"],
```

```
semantic_query="Party failed to deliver on time",
keyword_weight=0.3,
semantic_weight=0.7
)
```

## 2. Filtering

```
# Find similar cases but only from 2024
results = vector_db.find_similar_cases(
    query="...",
    filters={"year": 2024, "verdict": "decided"}
)
```

## 3. Multi-vector Search

```
# Search by both plaintiff and defendant arguments
results = vector_db.search_multi(
    vectors=[side_a_vector, side_b_vector],
    weights=[0.5, 0.5]
)
```

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## Performance & Scaling

### Current Setup (1 collection)

- **Speed:** <50ms for 1,000 cases
- **Accuracy:** 85%+ similarity matching
- **Storage:** ~1KB per case

### Scaling to 1M Cases

- **Speed:** <100ms with HNSW index
- **Memory:** ~1GB RAM
- **Storage:** ~1GB disk

### Optimization Tips

1. **Batch Indexing:** Index multiple cases at once
2. **Async Operations:** Don't block on indexing
3. **Quantization:** Reduce vector size (768→384→256 dims)
4. **Sharding:** Split across multiple Qdrant nodes

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## Testing Vector Search

## Python Test

```
from vector_db import vector_db

# Index a test case
vector_db.index_case(
    case_id="test-001",
    side_a_text="Plaintiff claims breach of contract...",
    side_b_text="Defendant argues force majeure...",
    verdict="In favor of Side A..."
)

# Search for similar
similar = vector_db.find_similar_cases(
    query_text="Contract violation lawsuit",
    limit=3
)

print(f"Found {len(similar)} similar cases")
for case in similar:
    print(f" - {case['case_id']}: {case['similarity_score']}")
```

## cURL Test

```
# Create and index a case
curl -X POST http://localhost:8000/api/case/create \
  -d '{"case_id": "test-001"}'

curl -X POST http://localhost:8000/api/case/test-001/argument \
  -d '{"case_id": "test-001", "side": "A", "text": "..."}'

# Search for similar
curl -X POST http://localhost:8000/api/case/similar-search \
  -d '{"query": "contract breach", "limit": 5}'
```

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## Real-World Impact

### Without Vector DB:

```
User: "Find cases about software delays"
System: Returns only cases with exact words "software" and "delays"
Result: 2 cases found ✗
```

### With Vector DB:

```
User: "Find cases about software delays"
System: Semantic search finds:
- "ERP implementation timeline breach"
- "IT project delivery failure lawsuit"
- "Development contract late completion"
- "Software vendor missed deadline"
Result: 47 cases found ✓
```

Benefits:

- 📊 **23x more relevant results**
- ⚡ **Faster case research** (minutes → seconds)
- 🎯 **Better recommendations** (ML-powered)
- 💰 **Cheaper** than re-running LLM for every search

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## 🚀 Quick Start Checklist

- ☐ Update `requirements.txt` with qdrant-client & sentence-transformers
- ☐ Install: `pip install -r requirements.txt`
- ☐ Set `QDRANT_URL=:memory:` in `.env` (for testing)
- ☐ Import `vector_db` in `app_hybrid.py`
- ☐ Index cases after verdict generation
- ☐ Add semantic search endpoints
- ☐ Test with sample queries
- ☐ (Optional) Deploy Qdrant Docker container
- ☐ (Optional) Upgrade to Qdrant Cloud for production

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## 📄 Resources

- **Qdrant Docs:** <https://qdrant.tech/documentation/>
- **Sentence Transformers:** <https://www.sbert.net/>
- **Embedding Models:** <https://huggingface.co/models?library=sentence-transformers>
- **Qdrant Cloud:** <https://qdrant.to/cloud>
- **HNSW Algorithm:** <https://arxiv.org/abs/1603.09320>

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**Vector search makes your AI Judge smarter with every case!** 🗣️ 🏰