elastic

Search & AI:
a new era

David Pilato | @dadoonet

Agenda

- "Classic" search and its limitations
- ML model and usage
- Vector search or hybrid search in Elasticsearch
- OpenAI's ChatGPT or LLMs with Elasticsearch

Elasticsearch

You Know, for Search

elastic

Elasticsearch

elastic

elastic

These are not the droids
you are looking for.

elastic

```
GET /_analyze
{
  "char_filter": [ "html_strip" ],
  "tokenizer": "standard",
  "filter": [ "lowercase", "stop", "snowball" ],
  "text": "These are <em>not</em> the droids
           you are looking for."
}
```

elastic

```
These are <em>not</em> the droids you are looking for.
{ "tokens": [{
      "token": "droid",
      "start_offset": 27, "end_offset": 33,
      "type": "<ALPHANUM>", "position": 4
    },{
      "token": "you",
      "start_offset": 34, "end_offset": 37,
      "type": "<ALPHANUM>", "position": 5
    }, {
      "token": "look",
      "start_offset": 42, "end_offset": 49,
      "type": "<ALPHANUM>", "position": 7
    }]}
```

Semantic
search
≠
Literal
matches

TODAY

X-wing starfighter squadron

TOMORROW

What ships and crews do I need to destroy an almost finished death star?
Or is there a secret weakness?

elastic

Elasticsearch

You Know, for **Vector** Search

elastic

What is a **Vector**?

Embeddings represent your data

Example: 1-dimensional vector

Realistic

Cartoon

Character	Vector
	[-1]
	[1]

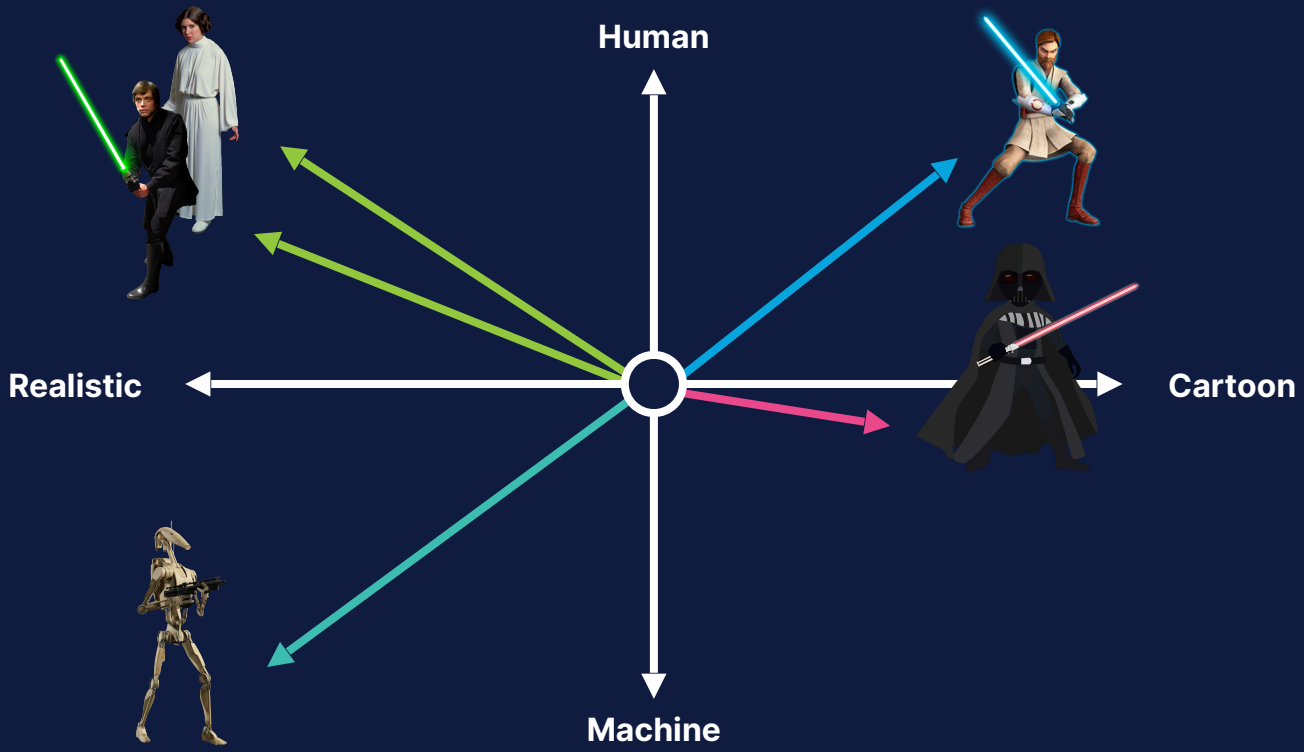
elastic

Multiple dimensions
represent different data aspects

Character	Vector
	[-1, 1]
	[1, 0]

elastic

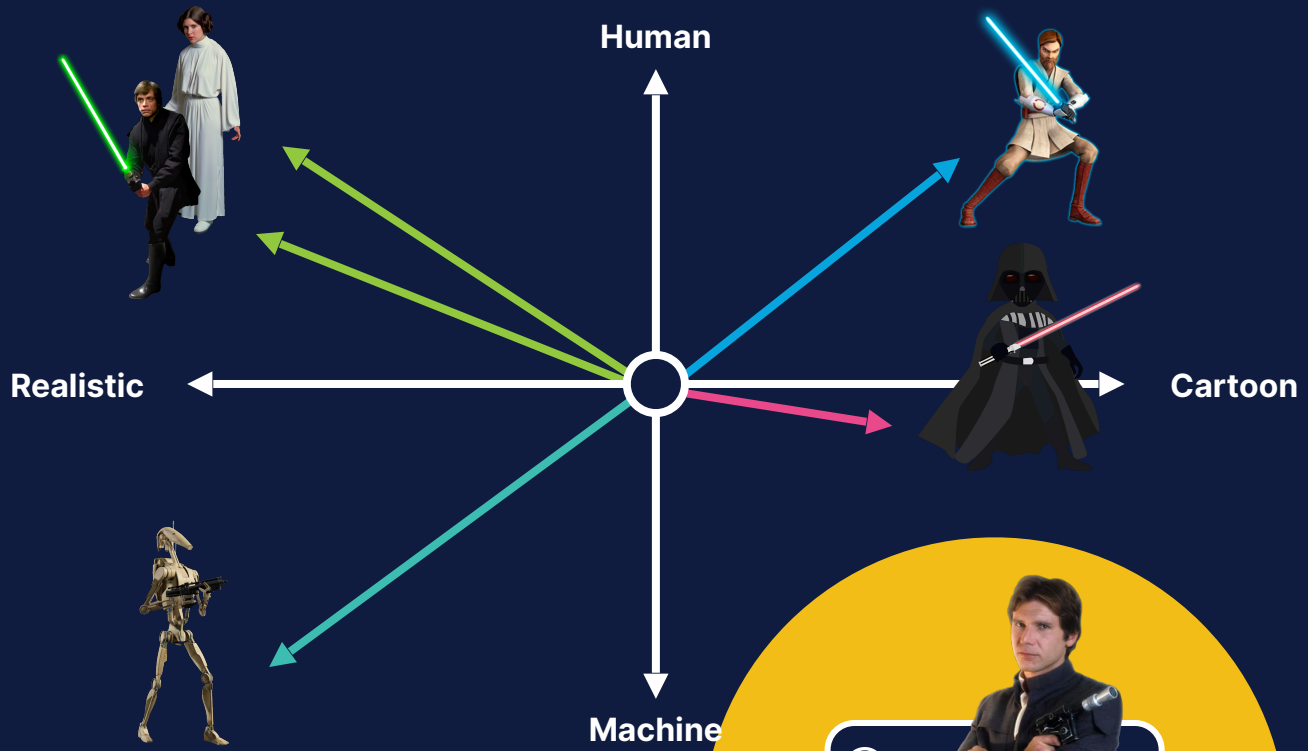
Similar data
is grouped together



Character	Vector
	[-1.0, 1.0]
	[1.0, 0.0]
	[-1.0, 0.8]
	[1.0, 1.0]
	[-1.0, -1.0]

elastic

Vector search ranks objects
by similarity (~relevance) to the query



Rank	Result
Query	
1	
2	
3	
4	
5	

elastic

Choice of Embedding Model

Start with Off-the Shelf Models

- Text data: Hugging Face (like Microsoft's E5)
- Images: OpenAI's CLIP

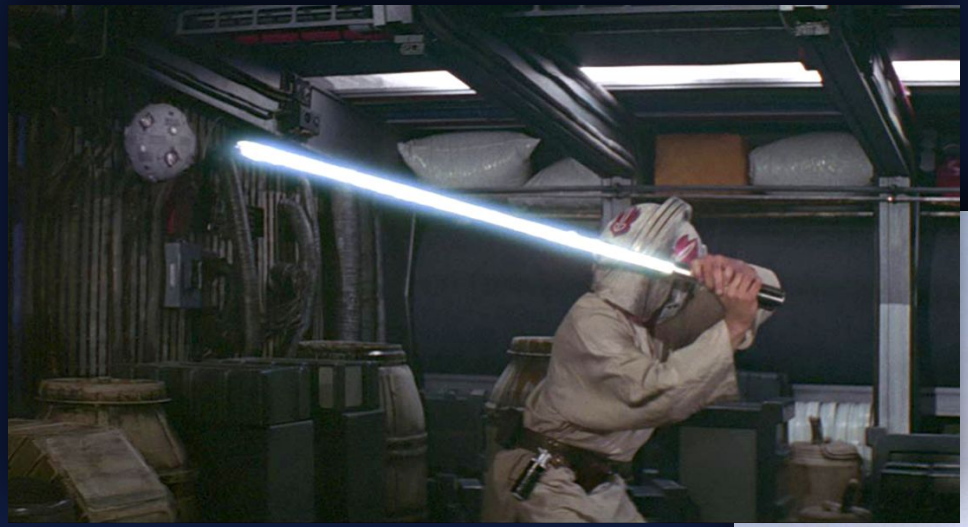
Extend to Higher Relevance

- Apply hybrid scoring
- Bring Your Own Model: requires expertise + labeled data

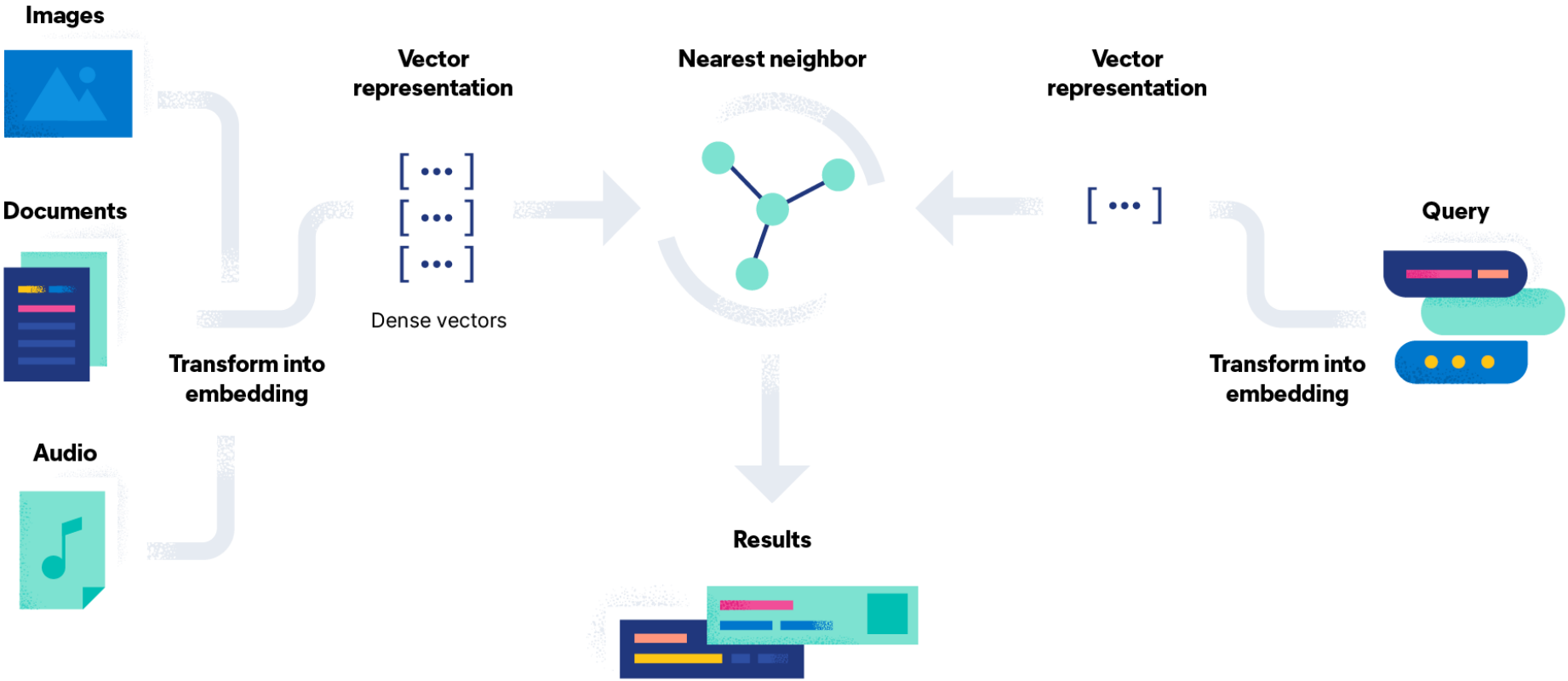
elastic

Problem

training vs actual use-case



Architecture of Vector Search

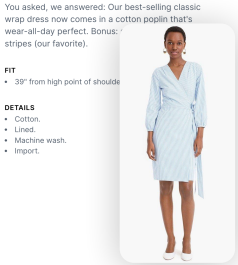


How do you

index **vectors**?

elastic

Data Ingestion and Embedding Generation



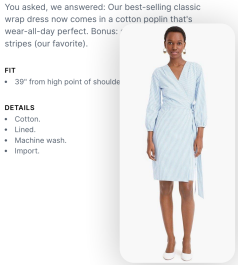
Source data

POST /_doc

```
{
  "_id":"product-1234",
  "product_name":"Summer Dress",
  "description":"Our best-selling…",
  "Price": 118,
  "color":"blue",
  "fabric":"cotton"
}
```

elastic

Data Ingestion and Embedding Generation



Source data


```
{
  "_id":"product-1234",
  "product_name":"Summer Dress",
  "description":"Our best-selling…",
  "Price": 118,
  "color":"blue",
  "fabric":"cotton",
  "desc_embedding":[0.452,0.3242,…],
  "img_embedding":[0.012,0.0,…]
}
```


PyTorch

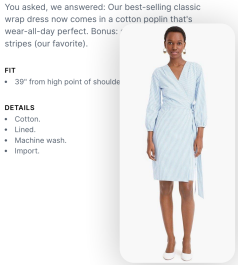
python™

POST /_doc

elastic

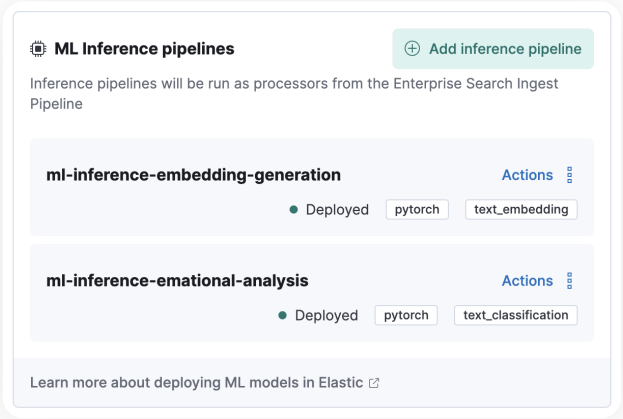
With Elastic ML

Commercial



Source data

```
POST /_doc
```

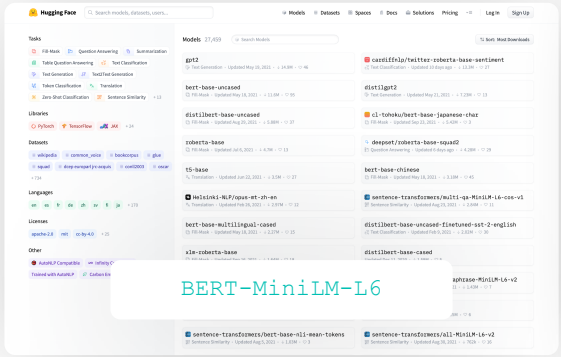


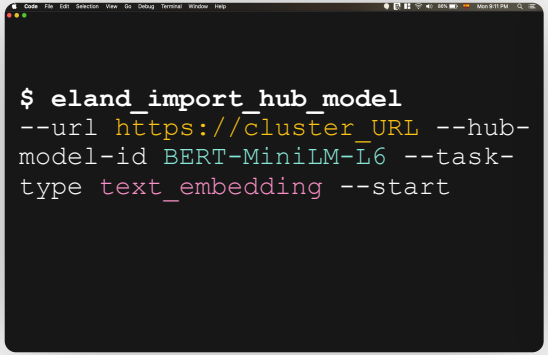

```
{
  "_id":"product-1234",
  "product_name":"Summer Dress",
  "description":"Our best-selling…",
  "Price": 118,
  "color":"blue",
  "fabric":"cotton",
  "desc_embedding":[0.452,0.3242,…]
}
```

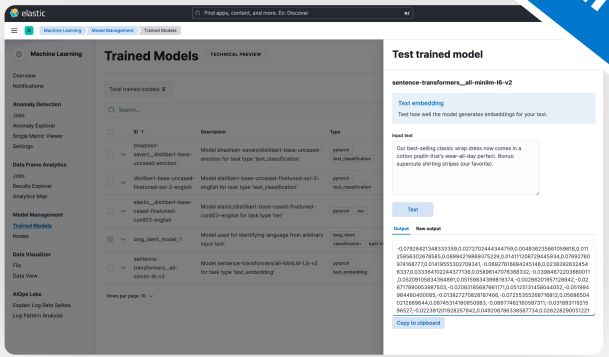

elastic

Eland Imports PyTorch Models

Commercial







PyTorch → eland →

Select the appropriate model

Load it

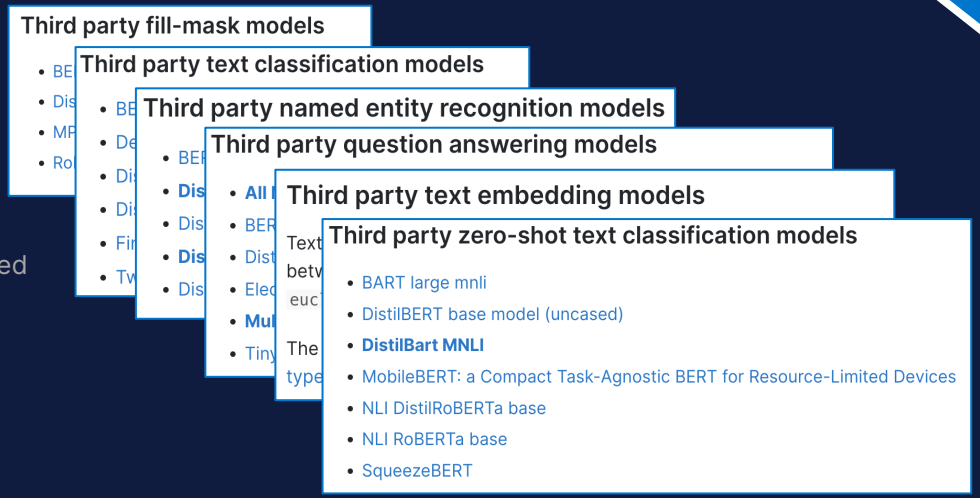
Manage models

elastic

Elastic's range of supported NLP models

Commercial

- **Fill mask model**
  Mask some of the words in a sentence and predict words that replace masks
- **Named entity recognition model**
  NLP method that extracts information from text
- **Text embedding model**
  Represent individual words as numerical vectors in a predefined vector space
- **Text classification model**
  Assign a set of predefined categories to open-ended text
- **Question answering model**
  Model that can answer questions given some or no context
- **Zero-shot text classification model**
  Model trained on a set of labeled examples, that is able to classify previously unseen examples



Full list at: ela.st/nlp-supported-models

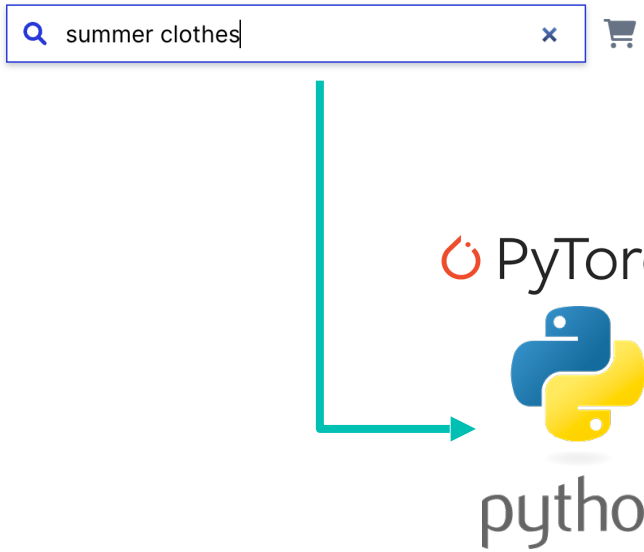
elastic

How do you

search **vectors**?

elastic

Vector Query




```
GET product-catalog/_search
{
 "query" : {
    "bool": {
      "must": [{
         "knn": {
           "field": "desc_embbeding",
           "num_candidates": 50,
           "query_vector": [0.123, 0.244,...]
         }
      }],
      "filter": {
        "term": {
          "department": "women"
        }
      }
    }
  },
  "size": 10
}
```

elastic

Vector Query

Transformer model

PyTorch

```
GET product-catalog/_search
{
 "query" : {
    "bool": {
      "must": [{
         "knn": {
           "field": "desc_embbeding",
           "num_candidates": 50,
           "query_vector_builder": {
             "text_embedding": {
               "model_text": "summer clothes",
               "model_id": <text-embedding-model>
             }
           }
         }
      }],
      "filter": {
        "term": {
          "department": "women"
        }
      }
    }
  },
  "size": 10
}
```

Commercial

elastic

Vector Search
components

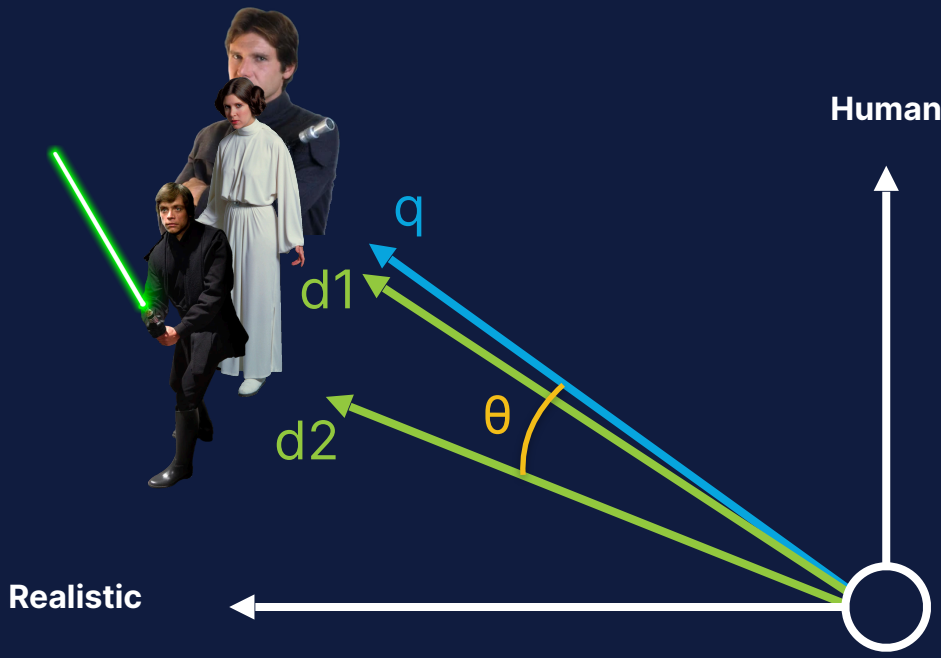
Search	Index	Generate
Query	**Mapping**	**Embedding**
`kNN`	`dense_vector`	Text embedding model (3rd party, local, in Elasticsearch)

elastic

But how does it

really work?

Similarity: cosine (cosine)

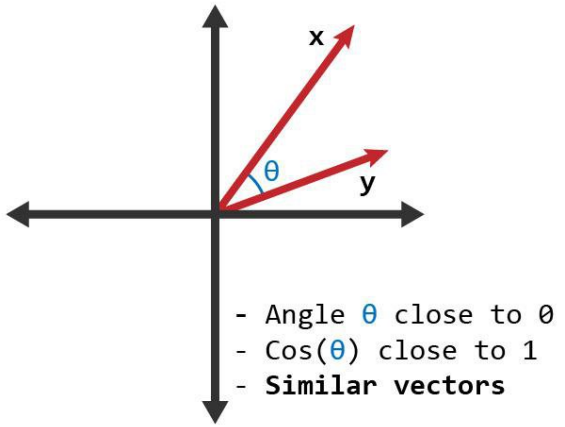


$$cos(\theta) = \frac{\vec{q} \times \vec{d}}{|\vec{q}| \times |\vec{d}|}$$

$$\_score = \frac{1 + cos(\theta)}{2}$$

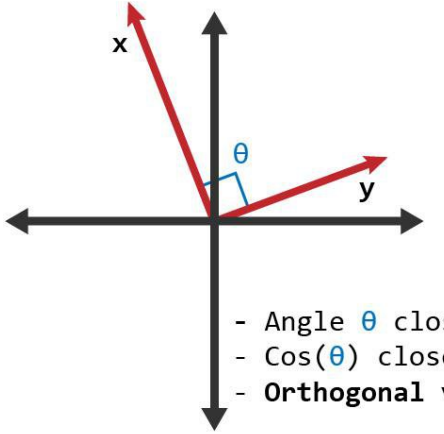
elastic

Similarity: cosine (cosine)



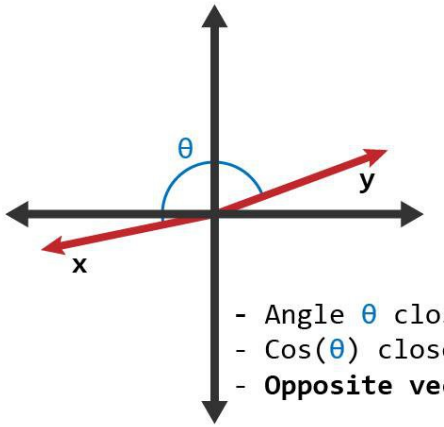
- Angle θ close to 0
- Cos(θ) close to 1
- **Similar vectors**

$$\_score = \frac{1+1}{2} = 1$$



- Angle θ close to 90
- Cos(θ) close to 0
- **Orthogonal vectors**

$$\_score = \frac{1+0}{2} = 0.5$$

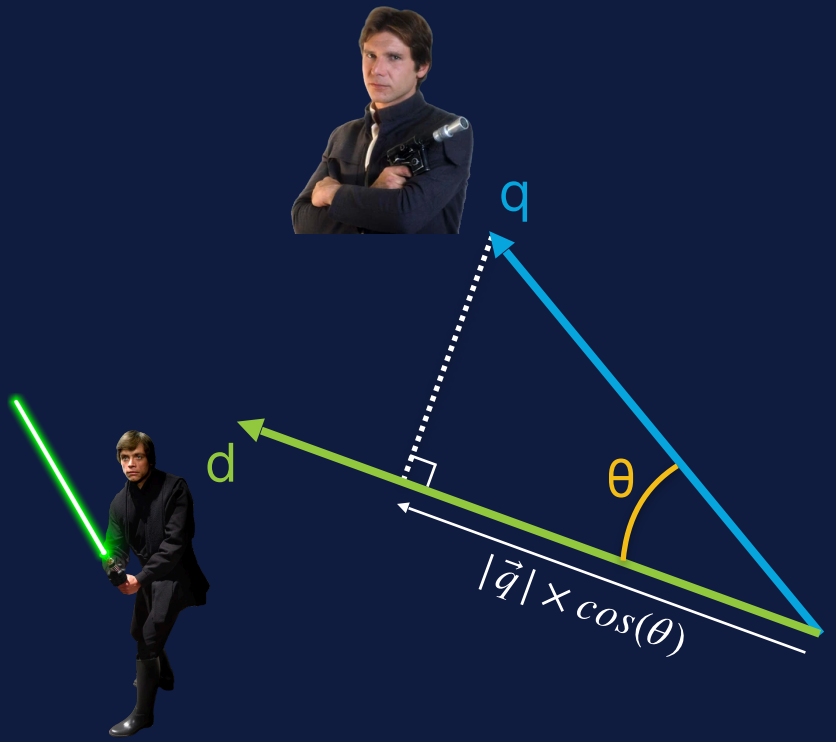


- Angle θ close to 180
- Cos(θ) close to -1
- **Opposite vectors**

$$\_score = \frac{1-1}{2} = 0$$

elastic

Similarity: Dot Product (dot_product)



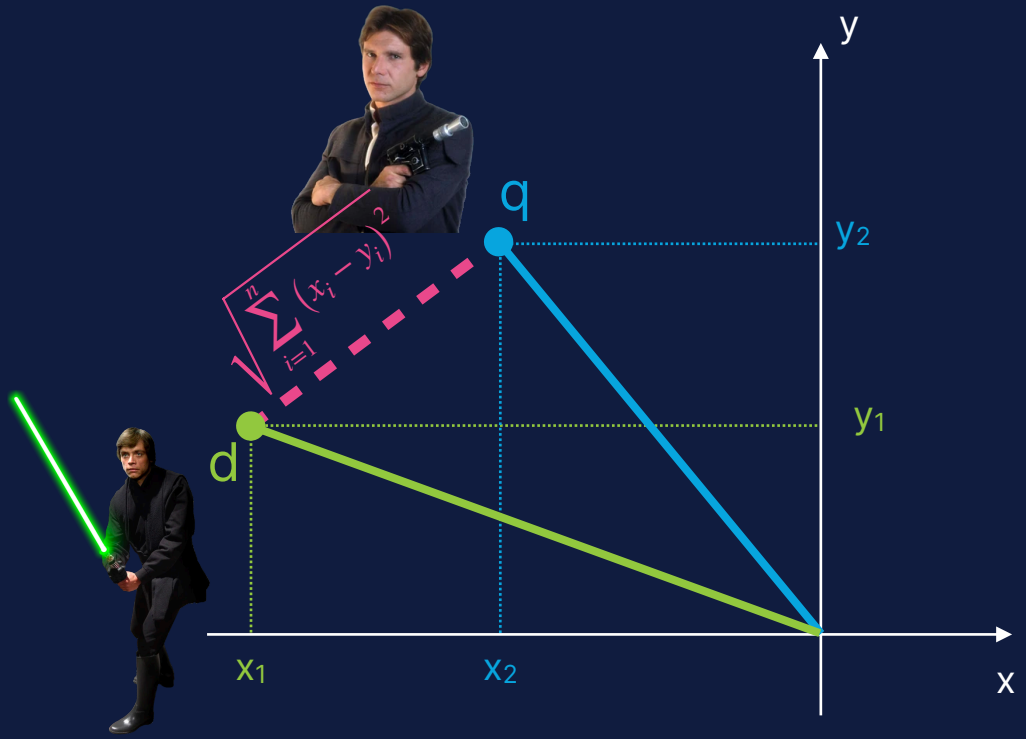
$$\vec{q} \times \vec{d} = |\vec{q}| \times cos(\theta) \times |\vec{d}|$$

$$\_score_{float} = \frac{1 + dot\_product(q, d)}{2}$$

$$\_score_{byte} = \frac{0.5 + dot\_product(q, d)}{32768 \times dims}$$

elastic

Similarity: Euclidean distance (l2_norm)



$$l2\_norm_{q,d} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

$$\_score = \frac{1}{1 + (l2\_norm_{q,d})^2}$$

elastic

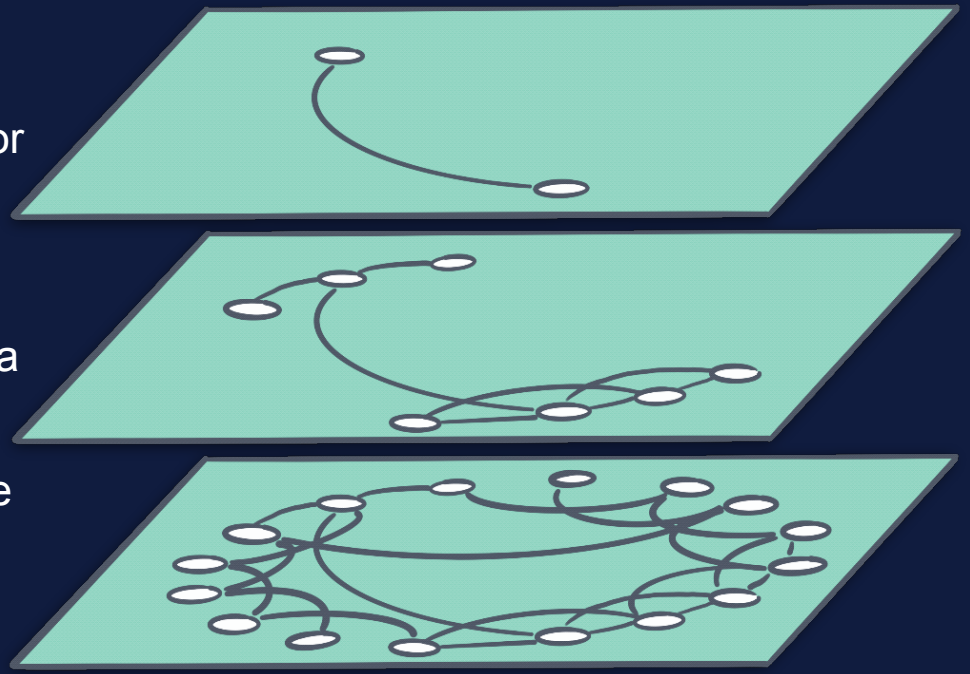
Brute Force

elastic

Hierarchical Navigable Small Worlds (HNSW)

One popular approach

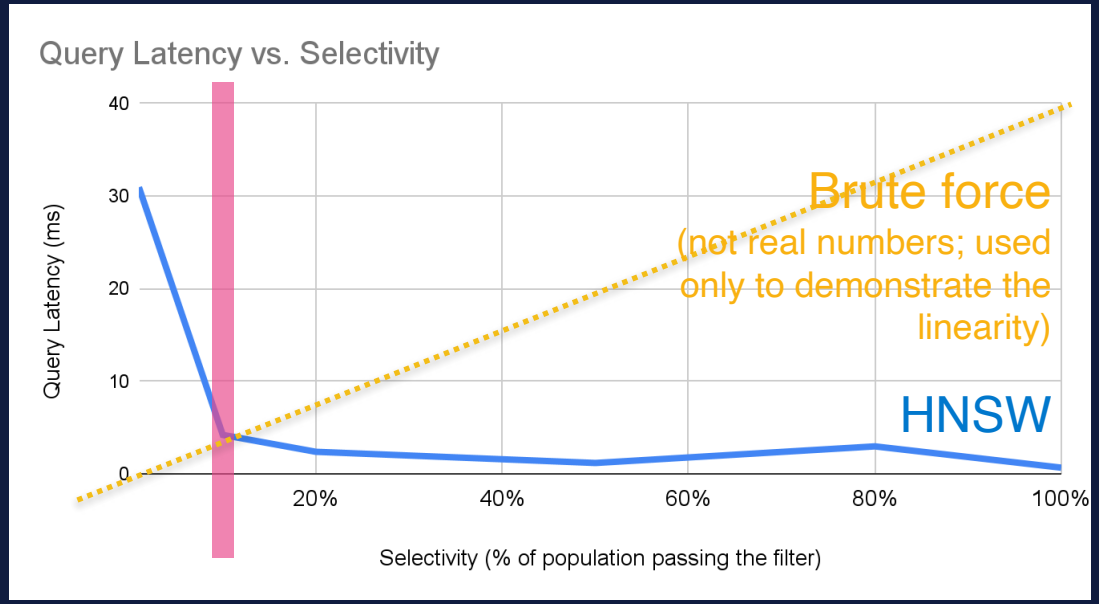
- **HNSW:** a layered approach that simplifies access to the nearest neighbor
- **Tiered:** from coarse to fine approximation over a few steps
- **Balance:** Bartering a little accuracy for a lot of scalability
- **Speed:** Excellent query latency on large scale indices



elastic

Filtering KNN Vector Similarity

Automatically choose between brute force and HNSW

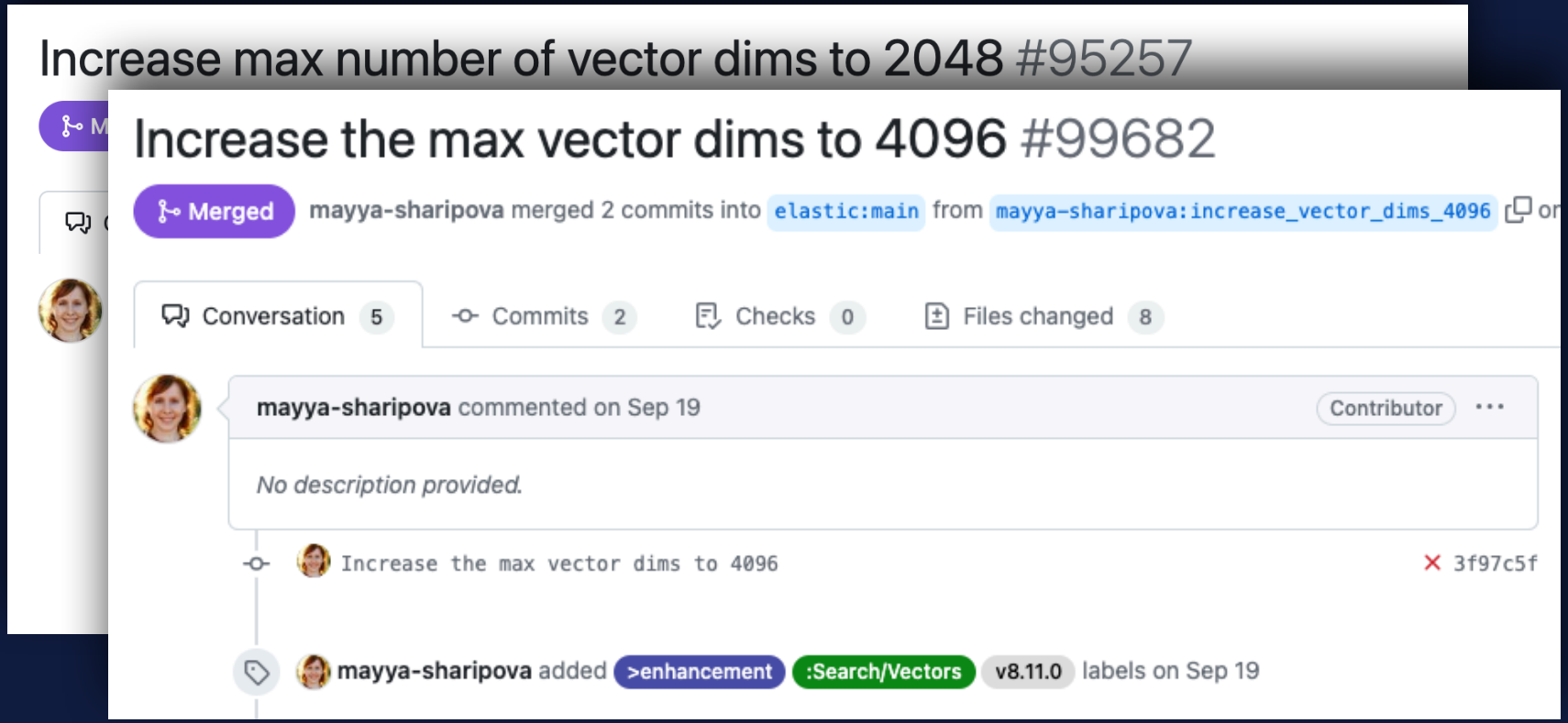


Bound worst case to 2*(brute force)

- Brute force scales O(n) of filtered
- HNSW scales ~O(log(n)) of all docs

elastic

Elasticsearch + Lucene = fast progress ❤️



elastic

Scaling Vector Search

Vector search

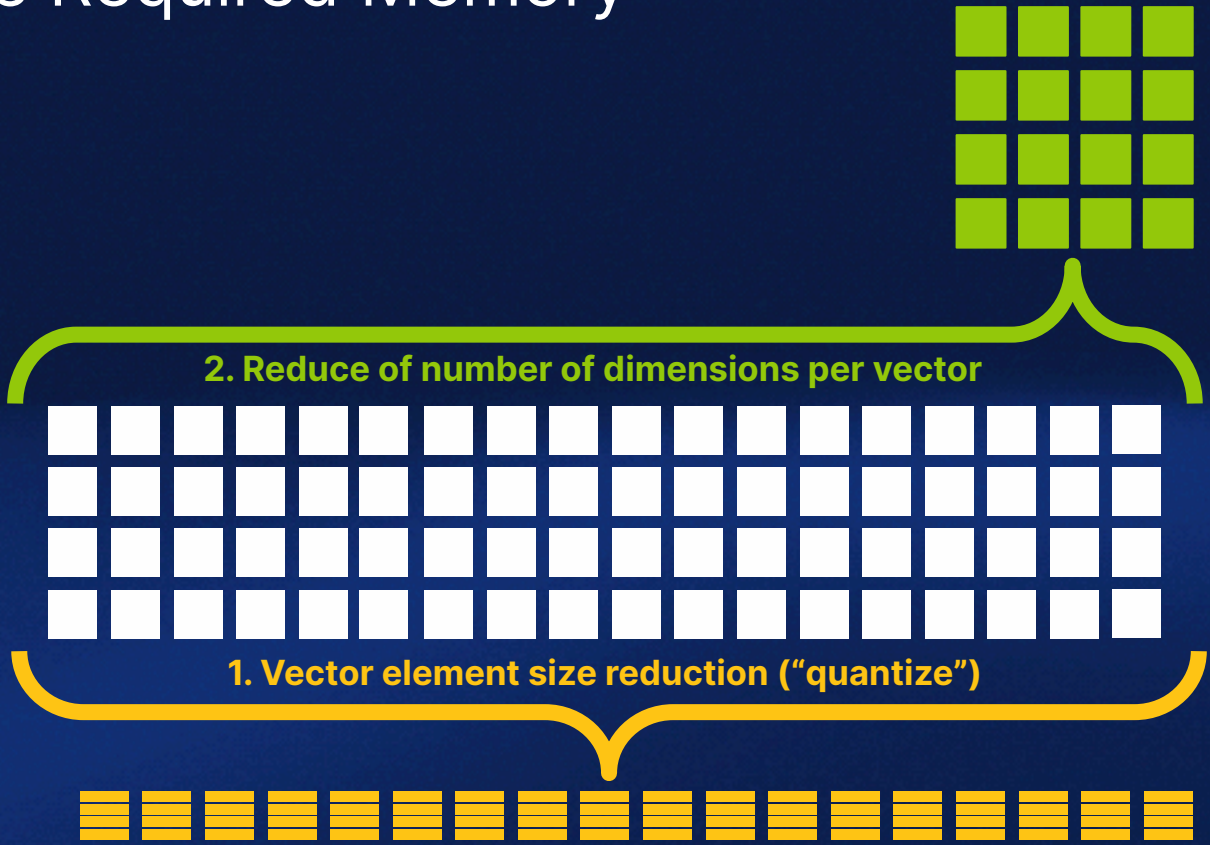
1. Needs lots of memory
2. Indexing is slower
3. Merging is slow

* Continuous improvements in Lucene + Elasticsearch

Best practices

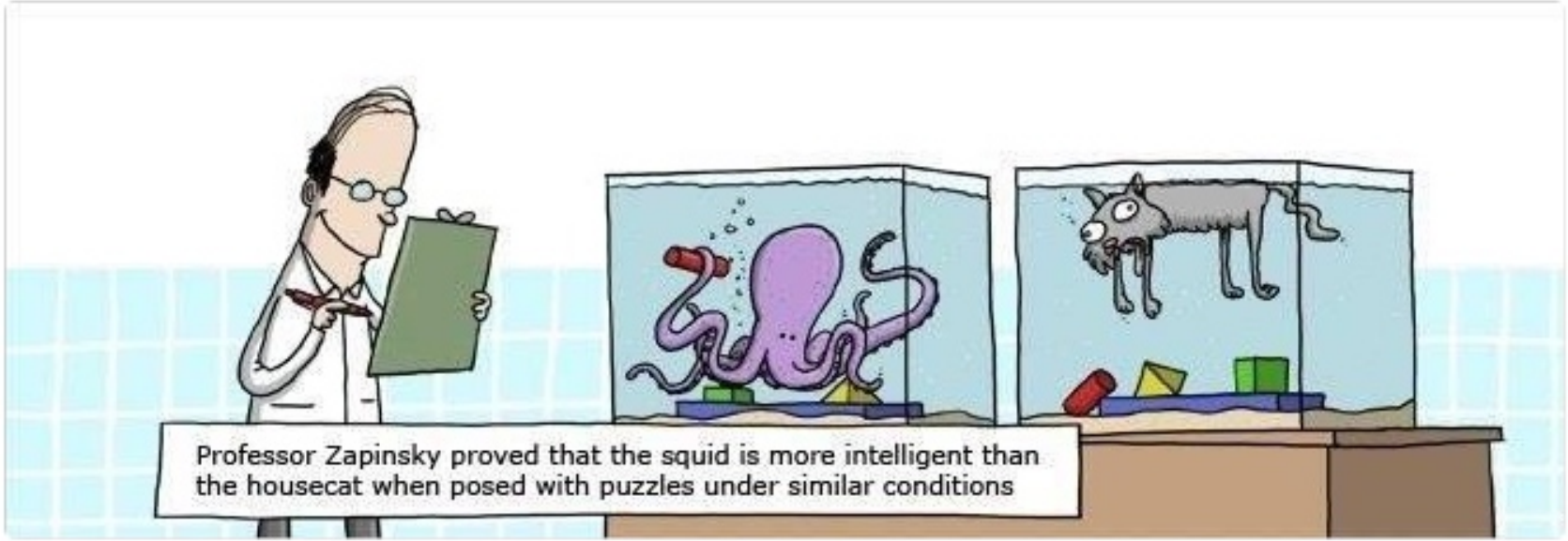
1. Avoid searches during indexing
2. Exclude vectors from _source
3. Reduce vector dimensionality
4. Use byte rather than float

Reduce Required Memory



elastic

Benchmarketing



elastic

https://github.com/erikbern/ann-benchmarks

Add Elasticsearch KNN #401

Merged **erikbern** merged 1 commit into `erikbern:main` from `ceh-forks:elasticsearch` last week

Conversation 5 | Commits 1 | Checks 34 | Files changed 4

ceh commented last week • edited Contributor

Add an implementation for Elasticsearch KNN search. Fixes #298.

- Supports specifying `index_options` via arg groups, with one entry for Elasticsearch's default settings for M and EF.
- Supports specifying `num_candidates` via query args.

What do you think **@erikbern**, **@alexklibisz**?

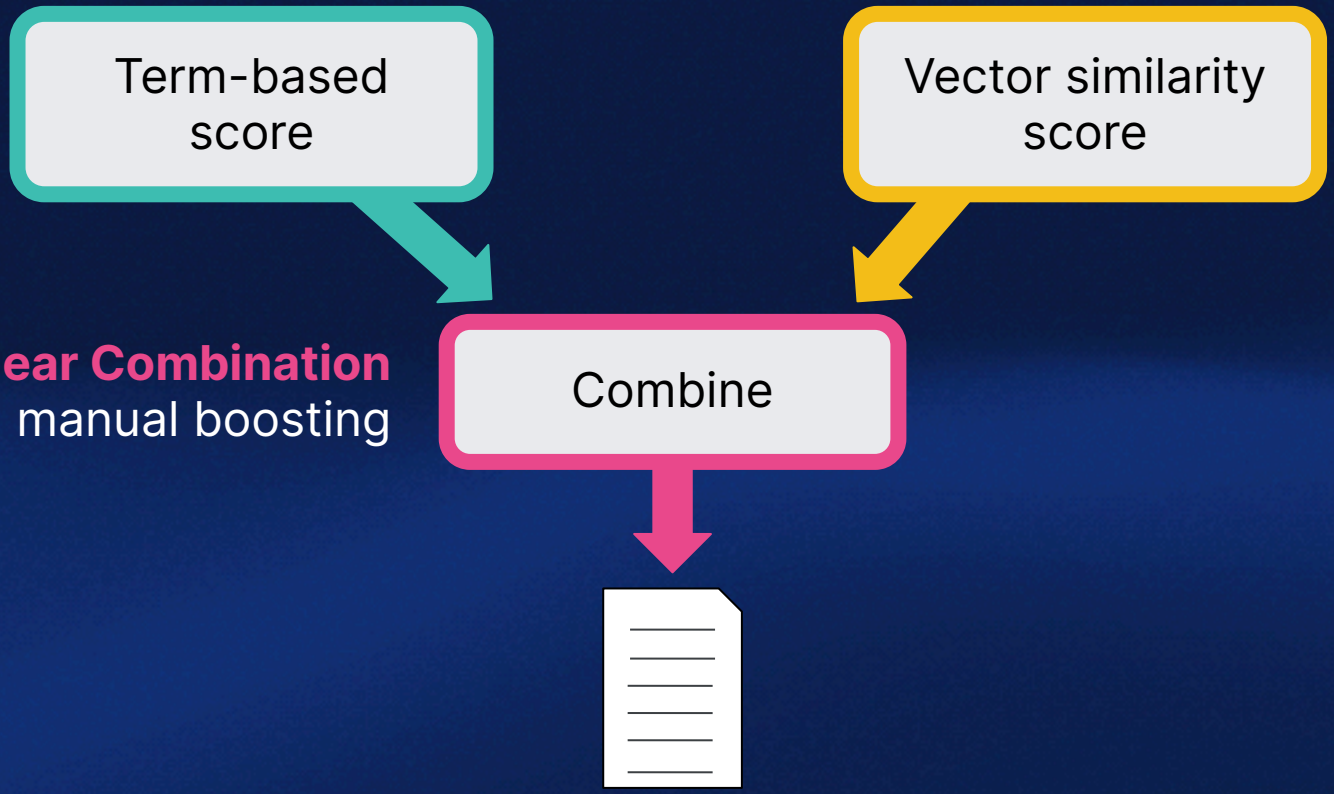
elastic

Elasticsearch

You Know, for **Hybrid** Search

elastic

Hybrid scoring



Linear Combination
manual boosting

```
GET product-catalog/_search
{
  "query" : {
    "bool" : {
      "must" : [{
        "match": {
          "description": {
            "query": "summer clothes",
            "boost": 0.1
          }
        }
      },{
        "knn": {
          "field": "desc_embbeding",
          "query_vector": [0.123, 0.244,...],
          "num_candidates": 50,
          "boost": 2.0,
          "filter": {
            "term": {
              "department": "women"
            }
          }
        }
      }],
      "filter" : {
        "range" : { "price": { "lte": 30 } }
      }
    }
  }
}
```

summer clothes

pre-filter

post-filter

elastic

```
GET product-catalog/_search
{
  "query" : {
    "bool" : {
      "must" : [{
        "match": {
          "description": {
            "query": "summer clothes",
            "boost": 0.1
          }
        }
      },{
        "knn": {
          "field": "image-vector",
          "query_vector": [54, 10, -2],
          "num_candidates": 50,
          "boost": 1.0
        }
      },{
        "knn": {
          "field": "title-vector",
          "query_vector": [1, 20, -52, 23, 10],
          "num_candidates": 10,
          "boost": 2.0
        }
      }]
    }
  }
}
```

elastic

ELSER

Elastic Learned Sparse EncodER

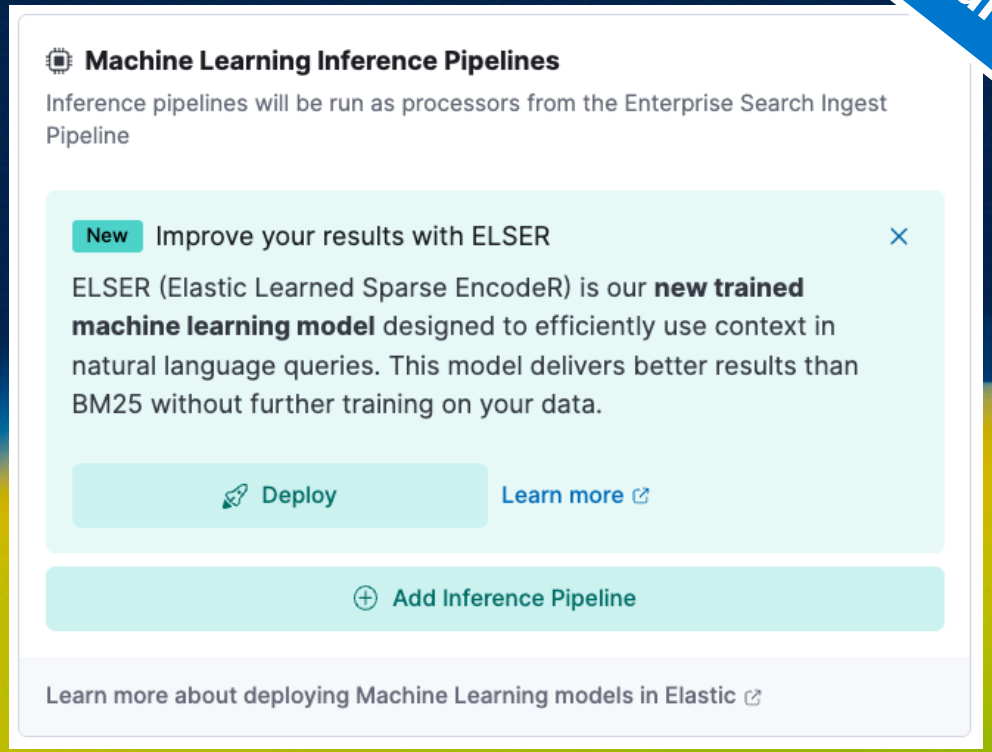
Commercial

text_expansion

Not BM25 or (dense) vector

Sparse vector like BM25

Stored as inverted index



elastic

Inference within Elasticsearch

Commercial

```
PUT /_inference/<task_type>/<inference_id>
{
  "service": "<service>",
  "service_settings": {},
  "task_settings": {}
}
```

- Amazon Bedrock
- Anthropic
- Azure AI Studio
- Azure OpenAI
- Cohere
- Elasticsearch
- ELSER
- Google AI Studio
- Google Vertex AI
- Hugging Face
- Mistral
- OpenAI

- text_embedding
- completion
- rerank
- sparse_embedding

elastic

```
PUT /_inference/completion/openai_completion
{
    "service": "openai",
    "service_settings": {
        "api_key": "<api_key>",
        "model_id": "gpt-3.5-turbo"
    }
}
```

```
PUT /_inference/text_embedding/hugging_face_embeddings
{
    "service": "hugging_face",
    "service_settings": {
       "api_key": "<access_token>",
       "url": "<url_endpoint>"
    }
}
```

```
PUT /_inference/sparse_embedding/my_elser_model
{
  "service": "elser",
  "service_settings": {
    "num_allocations": 1,
    "num_threads": 1
  }
}
```

Commercial

elastic

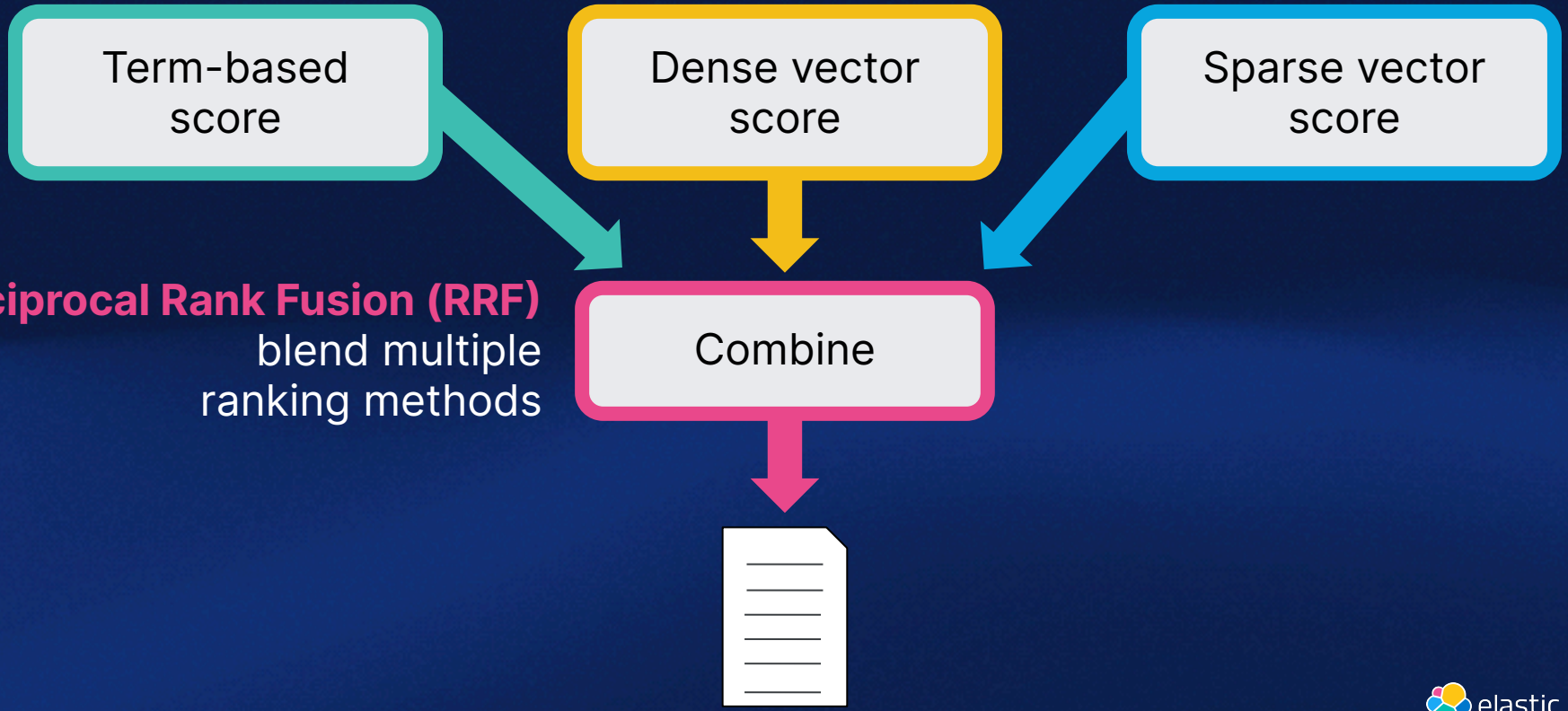
```
POST /_inference/sparse_embedding/my_elser_model
{
  "input": [
    "These are not the droids you are looking for.",
    "Obi-Wan never told you what happened to your father."
  ]
}
```

```
{
  "sparse_embedding": [{
                "lucas": 0.50047517,
                "ship": 0.29860738,
                "dragon": 0.5300422,
                "quest": 0.5974301,
                "dr": 2.1055143,
                "space": 0.49377063,
                "robot": 0.40398192,
                ...
```

Commercial

elastic

Hybrid ranking



Reciprocal Rank Fusion (RRF)
blend multiple ranking methods

elastic

Reciprocal Rank Fusion (RRF)

$$RRFscore(d \in D) = \sum_{r \in R} \frac{1}{k + r(d)}$$

D - set of docs
R - set of rankings as permutation on 1..|D|
k - typically set to 60 by default

Ranking Algorithm 1			
Doc	Score	r(d)	k+r(d)
A	1	1	61
B	0.7	2	62
C	0.5	3	63
D	0.2	4	64
E	0.01	5	65

Ranking Algorithm 2			
Doc	Score	r(d)	k+r(d)
C	1,341	1	61
A	739	2	62
F	732	3	63
G	192	4	64
H	183	5	65

Doc	RRF Score
A	1/61 + 1/62 = 0,0325
C	1/63 + 1/61 = 0,0323
B	1/62 = 0,0161
F	1/63 = 0,0159
D	1/64 = 0,0156

elastic

```
GET index/_search
{
  "retriever": {
    "rrf": {
     "retrievers": [{
          "standard" { "query": {
              "match": {...}
            }
          }
        },{
          "standard" { "query": {
              "text_expansion": {...}
            }
          }
        },{
          "knn": { ... }
        }
      ]
    }
  }
}
```

Hybrid Ranking

BM25f

+

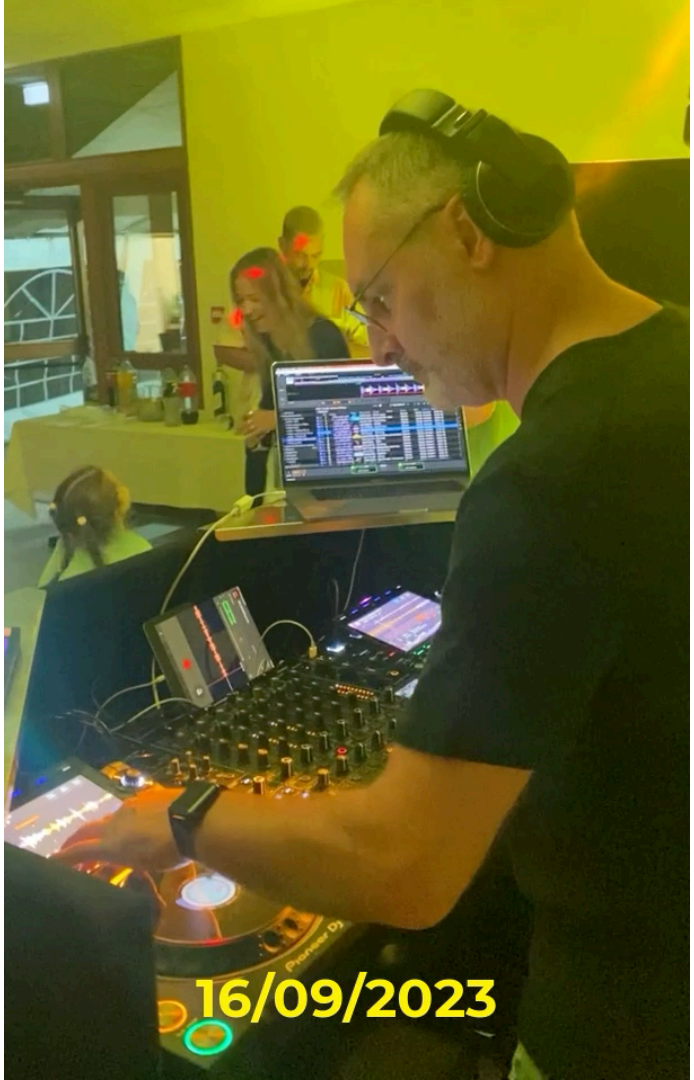
ELSER

+

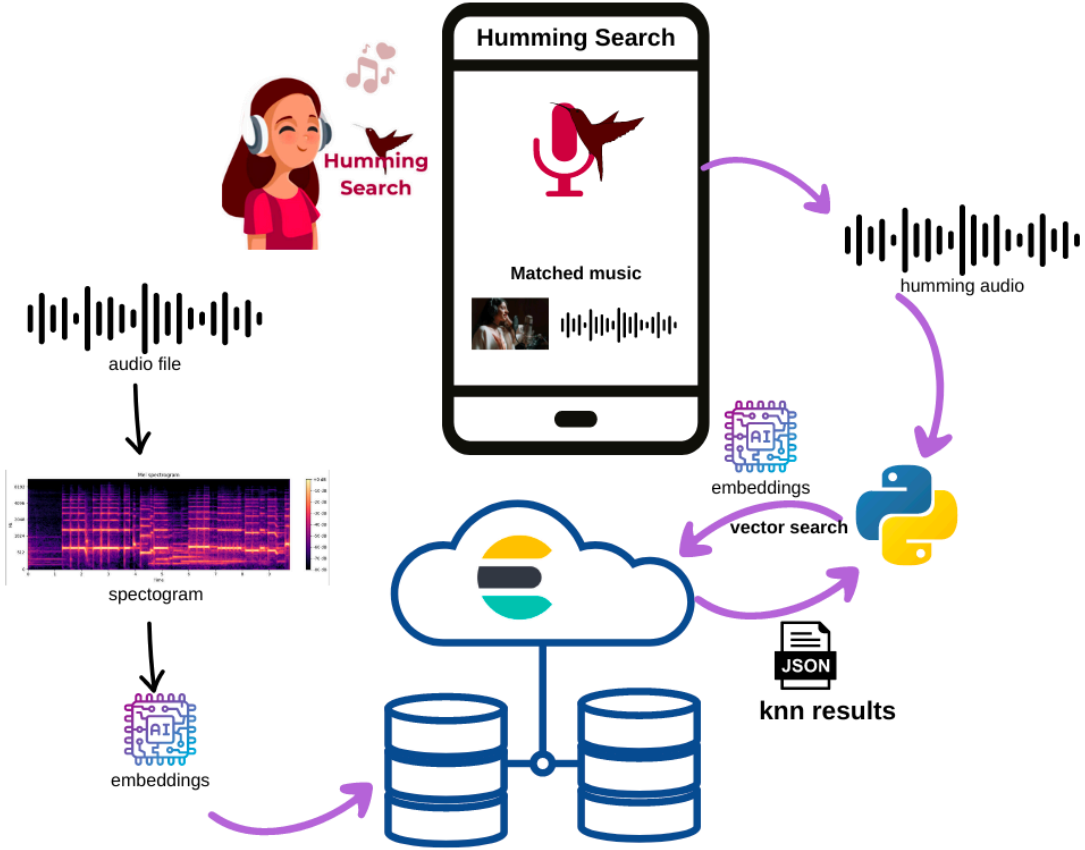
Vector

elastic

https://djdadoo.pilato.fr/



elastic



https://github.com/dadoonet/music-search/

elastic

ChatGPT

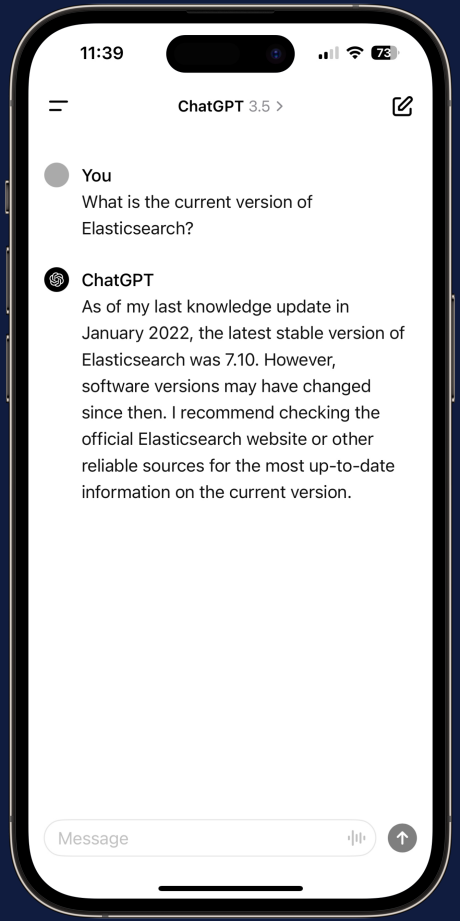
Elastic and LLM

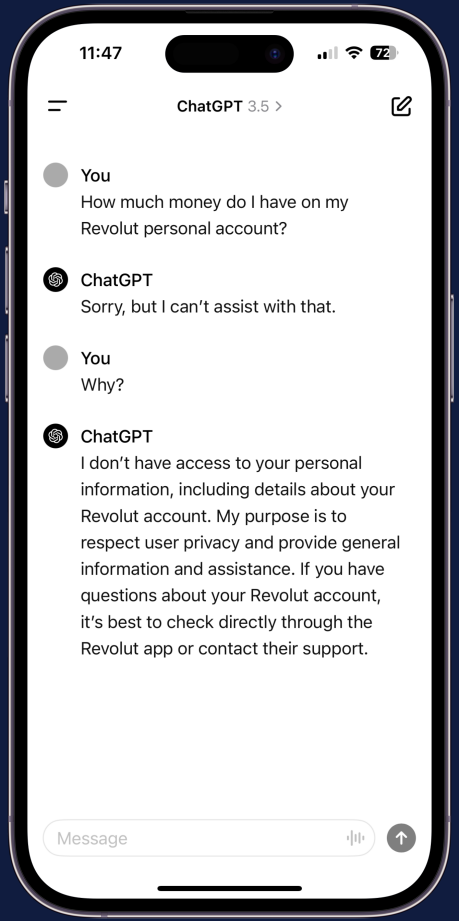
elastic


Gen AI
Search engines

LLM: opportunities and limits

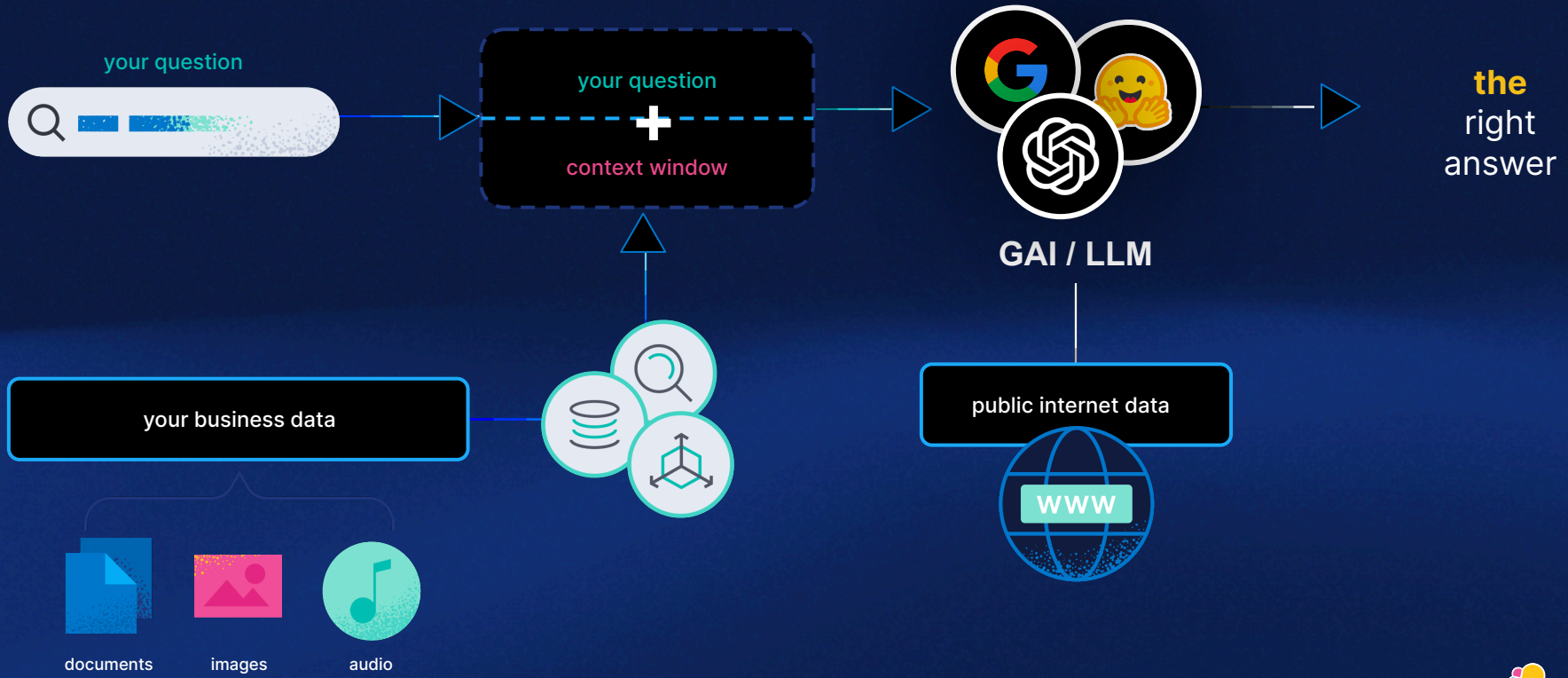
elastic


11:39
ChatGPT 3.5 >
You
What is the current version of Elasticsearch?
ChatGPT
As of my last knowledge update in January 2022, the latest stable version of Elasticsearch was 7.10. However, software versions may have changed since then. I recommend checking the official Elasticsearch website or other reliable sources for the most up-to-date information on the current version.
Message


11:47
ChatGPT 3.5 >
You
How much money do I have on my Revolut personal account?
ChatGPT
Sorry, but I can't assist with that.
You
Why?
ChatGPT
I don't have access to your personal information, including details about your Revolut account. My purpose is to respect user privacy and provide general information and assistance. If you have questions about your Revolut account, it's best to check directly through the Revolut app or contact their support.
Message

elastic

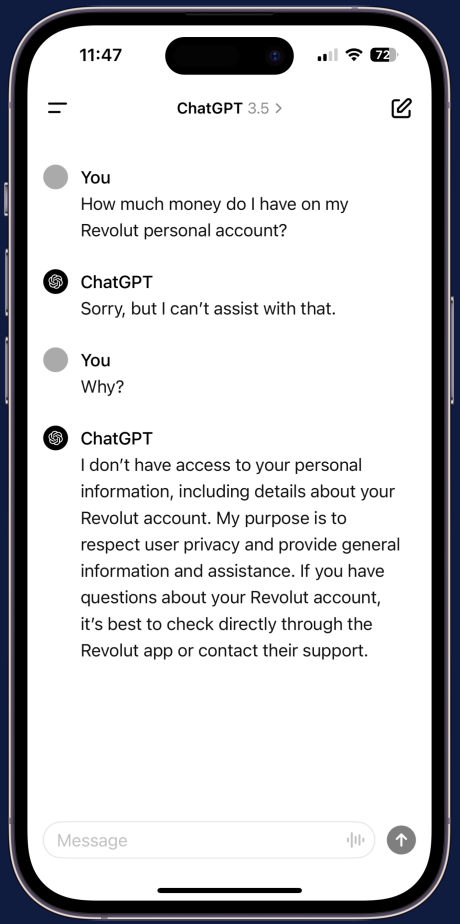
Retrieval Augmented Generation



elastic

Demo

Elastic Playground



Home | Online banking | Enviroment setup

me | Transaction search | Financial summary | Customer support

Search your transactions:

This search is not enabled by Elastic and reflects the kind of functionality available to customers today.

Submit

Date	Account	Description	Value	Opening balance	Closing balance
18/06/24	EL03-130981-Transmission	Inbound payment made from EL03-130981-Transmission, St.james's Plac (STJ): 864dce1b-bb95-47d5-87dd-7d02f3b10c3f	7419.0	-825.0	6594.0
18/06/24	EL03-130981-Transmission	Purchase at merchant: Southeastern Grocers, LLC, location: Fayetteville,AR	82.0	6594.0	6512.0
18/06/24	EL03-130981-Transmission	Purchase at merchant: Müller Holding Ltd. & Co. KG, location: Glendale,AZ	188.0	6512.0	6324.0
17/06/24	EL03-130981-Transmission	Payment made from EL03-130981-Transmission to Elwood Erickson, Mitie Grp. (MTO): d37085fc-1382-4593-9cb8-26e5526bd9a0	533.0	20.0	-513.0
17/06/24	EL03-130981-Transmission	Payment made from EL03-130981-Transmission to Classie Johns, Barclays (BARC): 75b603a2-1c1b-45e9-a7ec-4a551bf98a8d	312.0	-513.0	-825.0
16/06/24	EL03-130981-Transmission	Purchase at merchant: E-MART Inc., location: Fayetteville,AR	31.0	51.0	20.0
14/06/24	EL03-130981-Transmission	Purchase at merchant: Dick's Sporting Goods, Inc., location: Montgomery,AL	182.0	329.0	147.0
14/06/24	EL03-130981-Transmission	Purchase at merchant: Valor Holdings Co., Ltd., location: Louisville,KY	96.0	147.0	51.0
13/06/24	EL03-130981-Transmission	Purchase at merchant: The Save Mart Companies, location:	34.0	363.0	329.0

elastic

Conclusion

Making it easier

8.14

```
PUT /_inference/text_embedding/e5-small-multilingual
{
    "service": "elasticsearch",
    "service_settings": {
       "num_allocations": 1,
       "num_threads": 1,
       "model_id": ".multilingual-e5-small_linux-x86_64"
    }
}
```

elastic

Making it easier

8.14

```
PUT semantic-starwars
{
  "mappings": {
    "properties": {
      "quote": {
        "type": "text",
        "analyzer": "my_analyzer"
      },
      "quote_e5" : {
        "type" : "dense_vector"
}}}}
```

```
POST semantic-starwars/_doc
{
  "quote": "These are <em>not</em> the droids
    you are looking for.",
  "quote_e5": [ 0.5, 10, 6, ...]
}
```

```
GET semantic-starwars/_search
{
  "query": {
    "knn": {
      "field": "quote_e5"
      "k" : 10,
      "num_candidates": 100,
      "query_vector_builder": {
        "text_embedding": {
          "model_id": "e5-small-multilingual",
          "model_text": "search for an android"
}}}}}
```

elastic

`semantic_text` field type

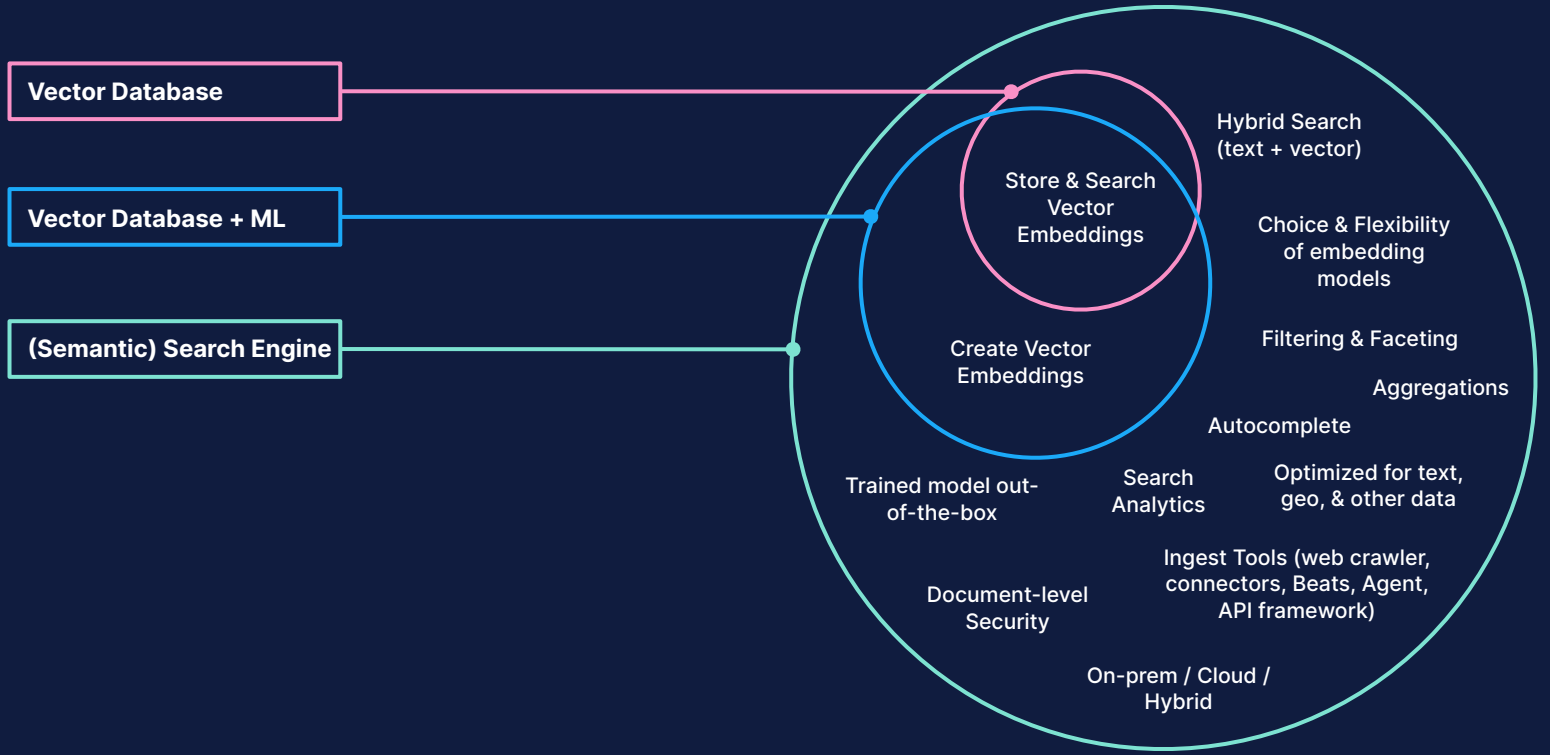
new in 8.15

```
PUT semantic-starwars
{
  "mappings": {
    "properties": {
      "quote": {
        "type": "text",
        "copy_to": [ "quote_e5" ]
      },
      "quote_e5" : {
        "type" : "semantic_text",
        "inference_id": "e5-small-multilingual"
}}}}
```

```
POST semantic-starwars/_doc
{
  "quote": "These are <em>not</em> the
    droids you are looking for."
}
```

```
GET semantic-starwars/_search
{
  "query": {
    "semantic": {
      "field": "quote_e5"
      "query" : "search for an android"
}}}
```

elastic


Vector Database
Vector Database + ML
(Semantic) Search Engine
Store & Search Vector Embeddings
Create Vector Embeddings
Hybrid Search (text + vector)
Choice & Flexibility of embedding models
Filtering & Faceting
Aggregations
Autocomplete
Optimized for text, geo, & other data
Search Analytics
Trained model out-of-the-box
Ingest Tools (web crawler, connectors, Beats, Agent, API framework)
Document-level Security
On-prem / Cloud / Hybrid

elastic

Elasticsearch

You Know, for **Semantic** Search

elastic

elastic

Search & AI:
a new era

David Pilato | @dadoonet