

“Talk to your Data”: Improving RAG solutions based on real-world experiences

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Gen AI Engineering Days

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- Generative AI in business settings
- Flexible and scalable backends
- All things .NET
- Pragmatic end-to-end architectures
- Developer productivity
- Software quality



What to expect (and what not):

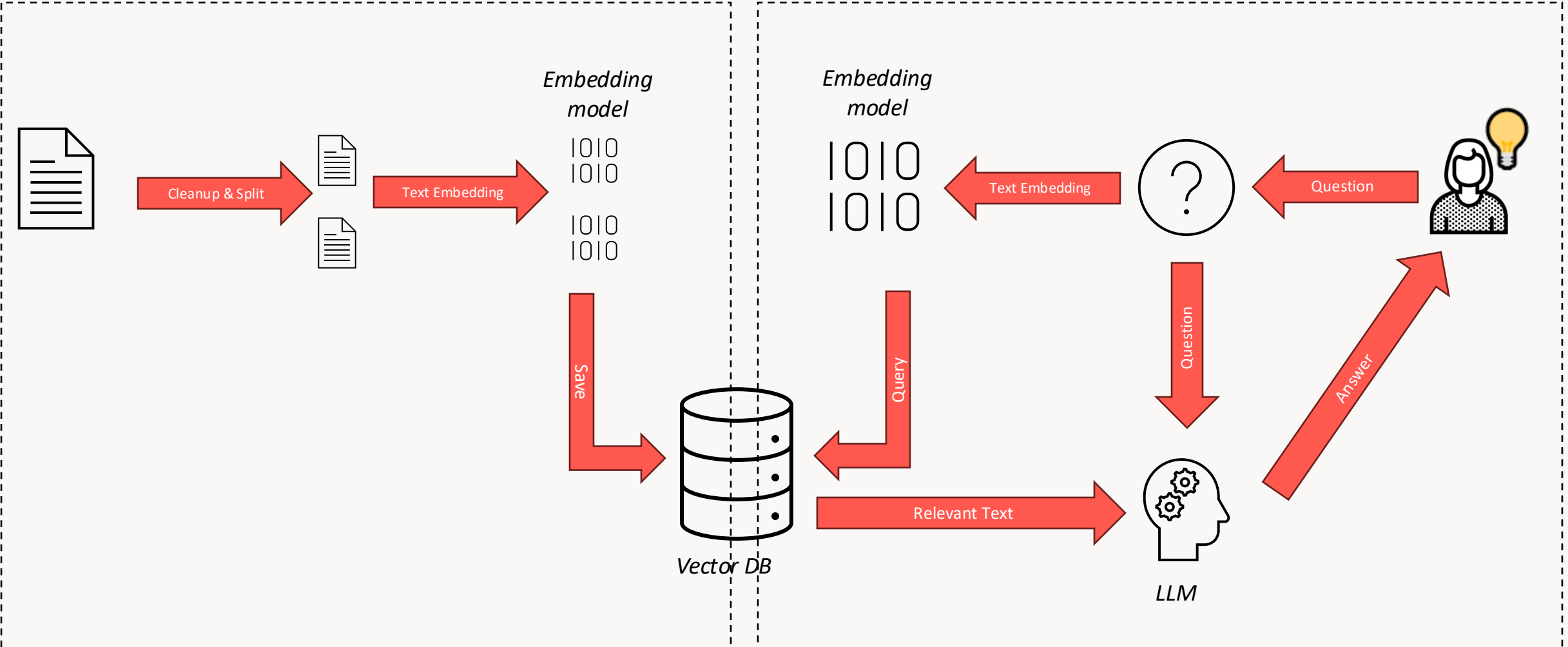
- Some background info and theory
- Overview over semantic search
- Problems and possible strategies
- Pragmatic approaches for your own data
- No C#, some Python 🤖
- No deep-dive into
 - LLMs
 - LangChain

Agenda

- Short Introduction to RAG
- Embeddings (and a bit of theory 🤖)
- Indexing
- Retrieval
- Not good enough? – Indexing II
 - HyDE & alternative indexing methods
- Conclusion

Introduction

Use case: Retrieval-augmented generation (RAG)



Other use-cases:

- Similarity determination
- Semantic search
- Semantic routing
- Semantic caching
- Categorization
- etc.

Semantic Search

- Classic search: lexical
 - Compares words, parts of words and variants
 - Classic SQL: WHERE 'content' LIKE '%searchterm%'
 - We can search only for things where we know that its somewhere in the text
- New: Semantic search
 - Compares for the same contextual meaning
 - "Das Rudel rollt das runde Gerät auf dem Rasen herum"
 - "The pack enjoys rolling a round thing on the green grass"
 - "Die Hunde spielen auf der Wiese mit dem Ball"
 - "The dogs play with the ball on the meadow"

Semantic Search

- How to grasp “semantics”?
- Computers only calculate on numbers
 - Computing is “applied mathematics”
- AI also only calculates on numbers

Semantic Search

- We need a numeric representation of text
 - Tokens
- We need a numeric representation of meaning
 - Embeddings

Tokens

- Similar to char tables (e.g. ASCII), just with larger elements
- Tokens are parts of text
 - Words
 - Syllables
 - Punctuation
 - ...
- Tokens are translated to token IDs
- Example: <https://platform.openai.com/tokenizer>

Embeddings

Embedding (math.)

- Topologic: Value of a high dimensional space is “embedded” into a lower dimensional space
- Natural / human language is very complex (high dimensional)
 - Task: Map high complexity to lower complexity / dimensions
- Injective function
- Similar to hash, or a lossy compression

Embeddings

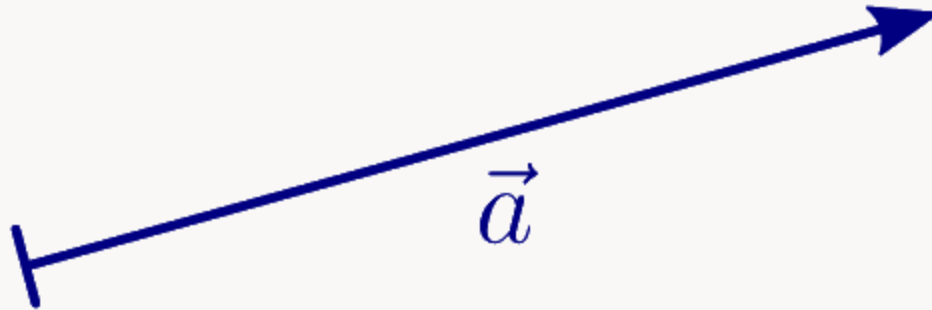
- Embedding model (specialized ML model) converting text into a numeric representation of its meaning
- Representation is a Vector in an n-dimensional space
 - n floating point values
 - OpenAI
 - “text-embedding-ada-002” uses 1536 dimensions
 - “text-embedding-3-small” 512 and 1536
 - “text-embedding-3-large” 256, 1024 and 3072
 - Huggingface models have a very wide range of dimensions

Embeddings

- Embedding models are unique
- Each dimension has a different meaning, individual to the model
- Vectors from different models are incompatible with each other
 - they live in different vector spaces
- Some embedding models are multi-language, but not all
- In an LLM, also the first step is to embed the input into a lower dimensional space

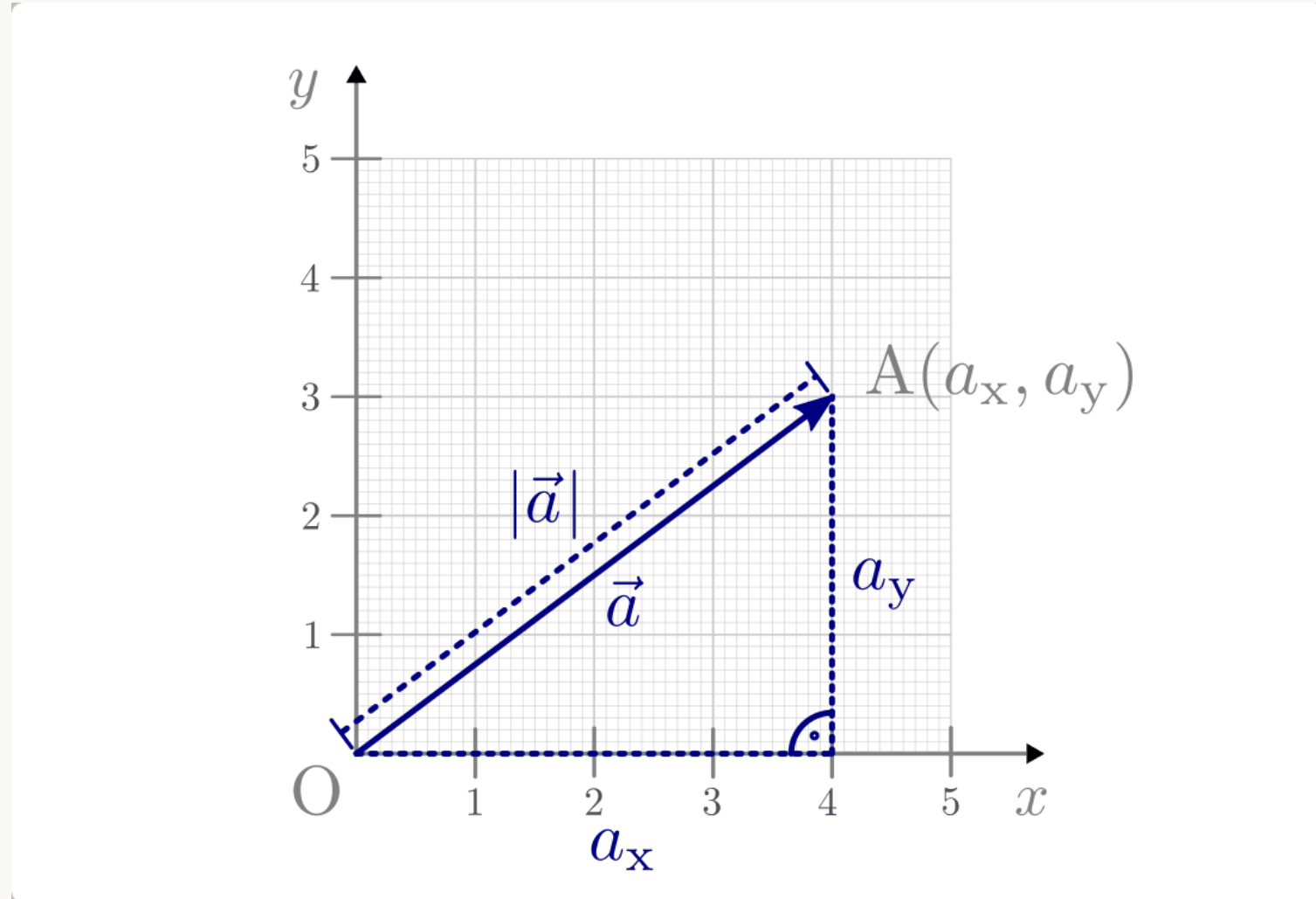
What is a vector?

- Mathematical quantity with a direction and length
- $\vec{a} = \begin{pmatrix} a_x \\ a_y \end{pmatrix}$



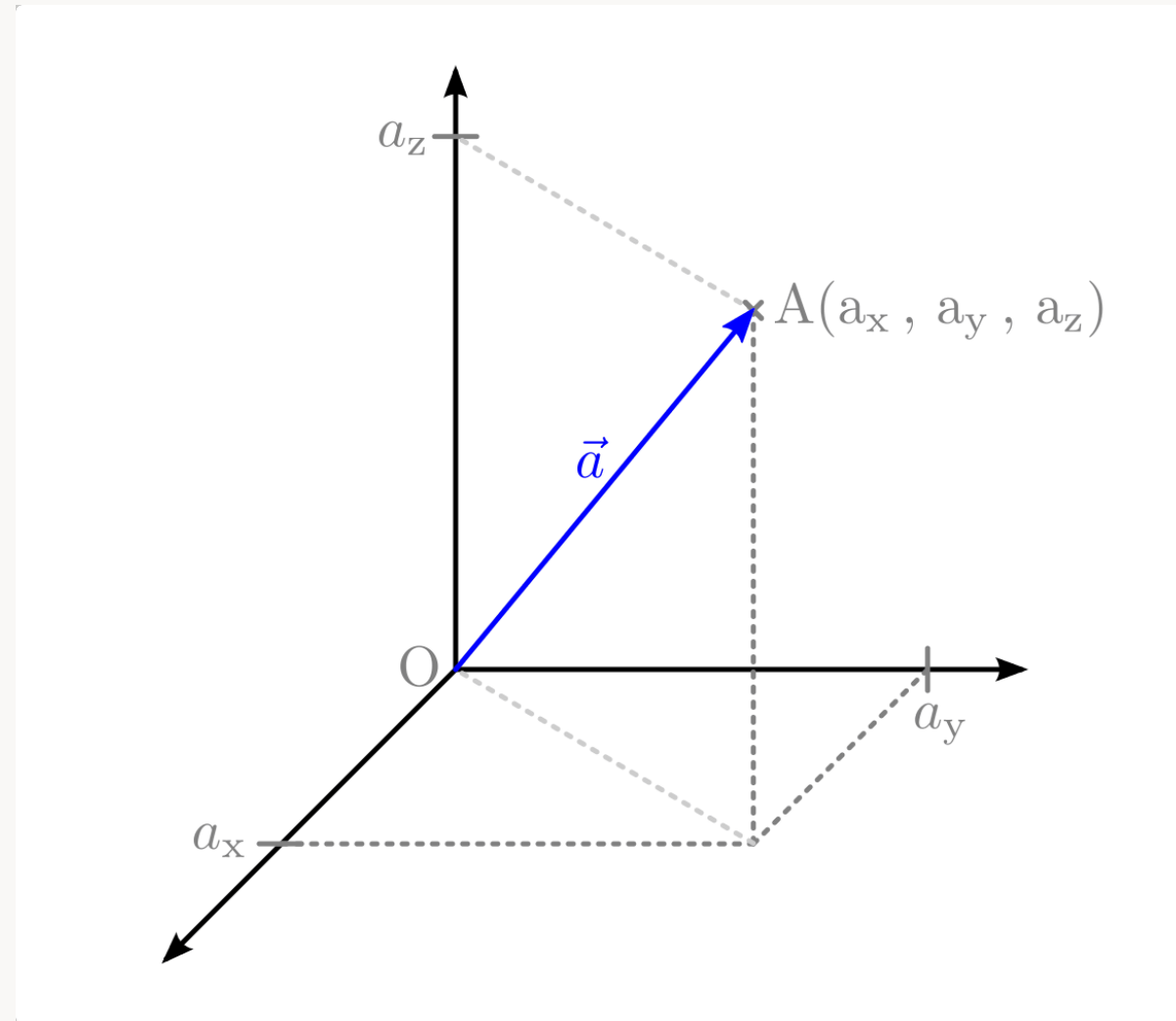
Vectors in 2D

$$\vec{a} = \begin{pmatrix} a_x \\ a_y \end{pmatrix}$$



Vectors in 3D

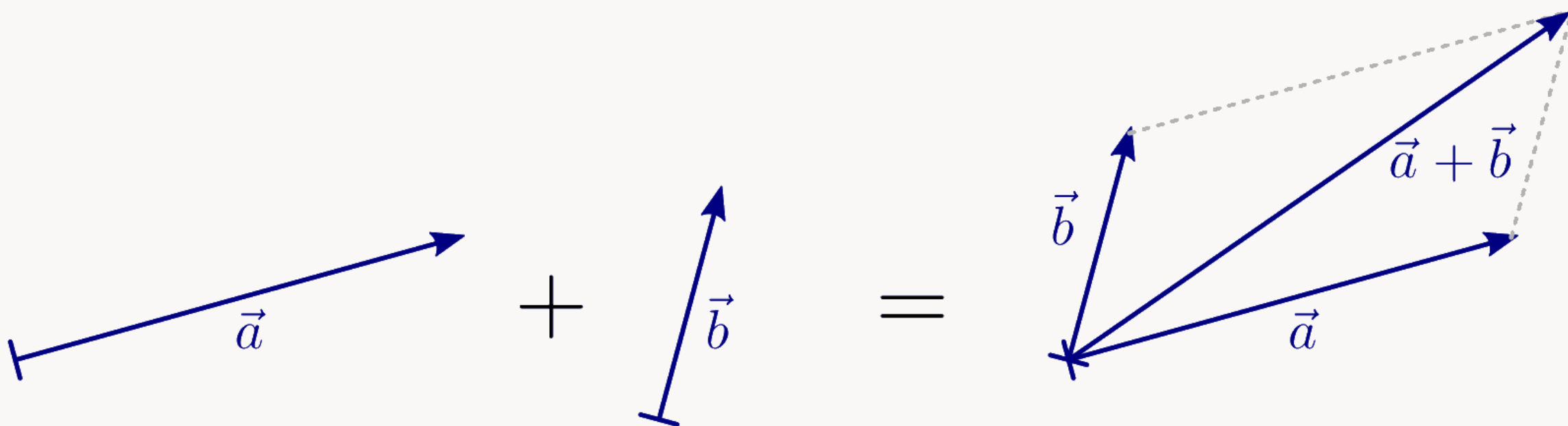
$$\vec{a} = \begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix}$$



Vectors in multidimensional space

$$\vec{a} = \begin{pmatrix} a_u \\ a_v \\ a_w \\ a_x \\ a_y \\ a_z \end{pmatrix}$$

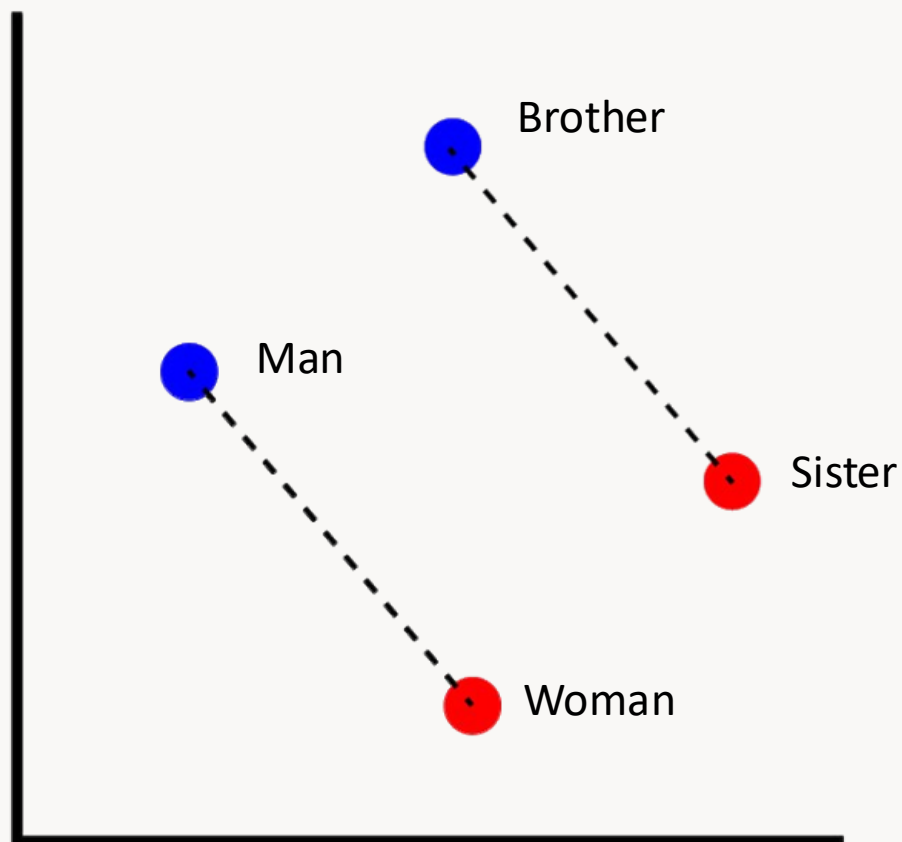
Calculation with vectors



Word2Vec

Mikolov et al., Google, 2013

$$\textit{Brother} - \textit{Man} + \textit{Woman} \approx \textit{Sister}$$



Embedding-Model

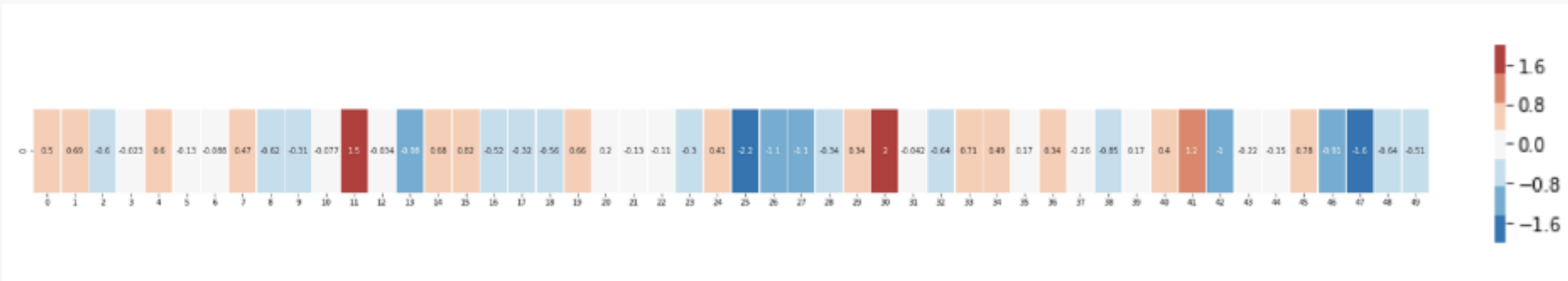
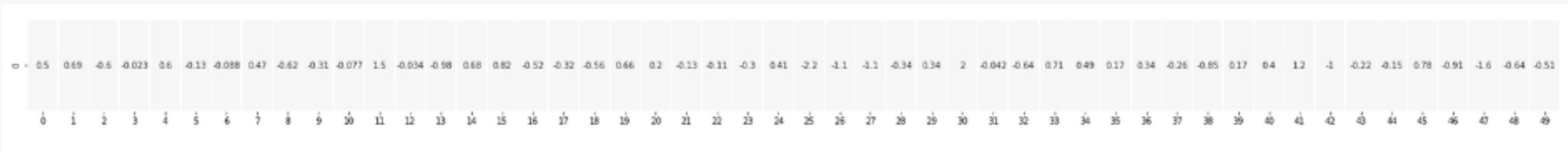
- Task: Create a vector from an input
 - Extract meaning / semantics
- Embedding models usually are very shallow & fast
Word2Vec is only two layers
- Similar to the first step of an LLM
 - Convert text to values for input layer
- This comparison is very simplified, but one could say:
 - The embedding model 'maps' the meaning into the model's 'brain'

Vectors from your Embedding-Model

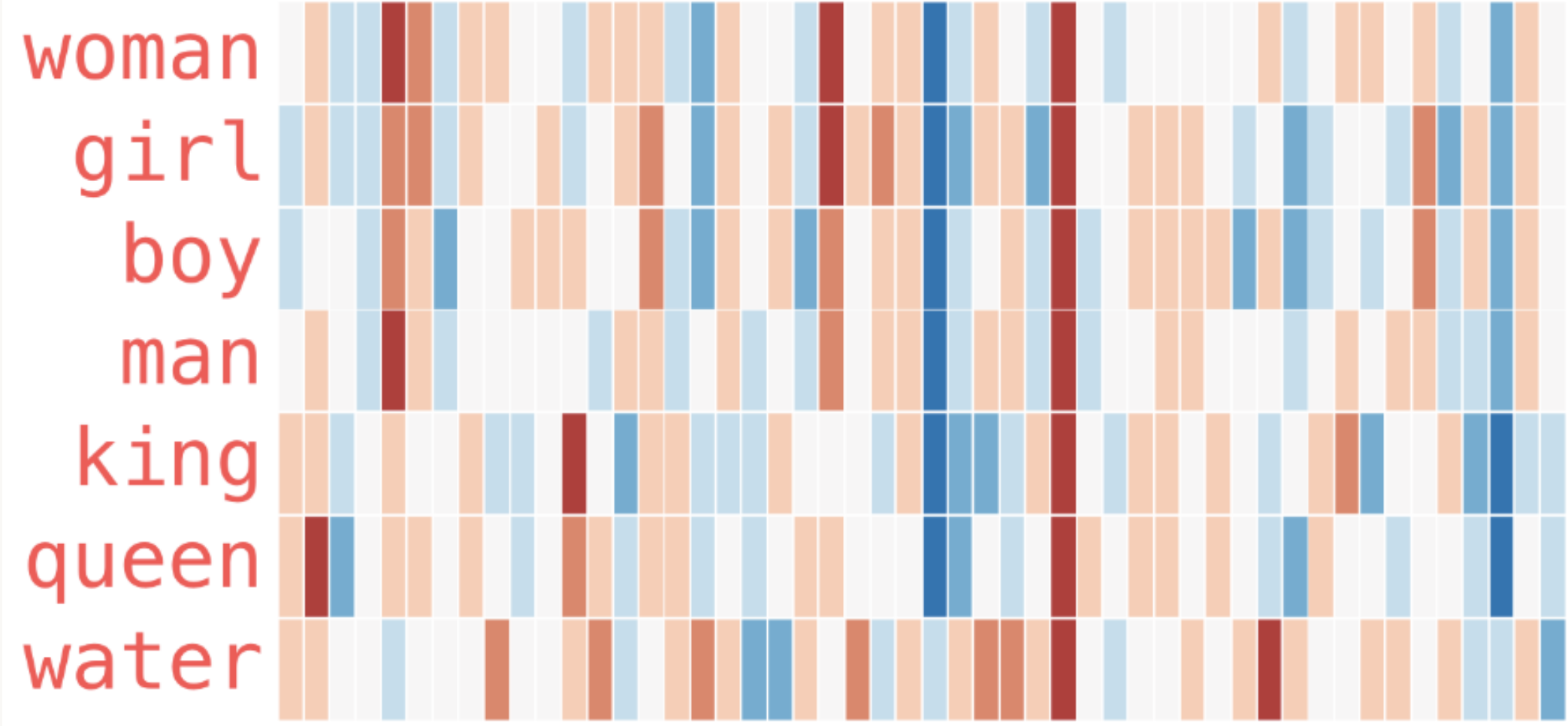


Embedding-Model

[0.50451, 0.68607, -0.59517, -0.022801, 0.60046, -0.13498, -0.08813, 0.47377, -0.61798, -0.31012, -0.076666, 1.493, -0.034189, -0.98173, 0.68229, 0.81722, -0.51874, -0.31503, -0.55809, 0.66421, 0.1961, -0.13495, -0.11476, -0.30344, 0.41177, -2.223, -1.0756, -1.0783, -0.34354, 0.33505, 1.9927, -0.04234, -0.64319, 0.71125, 0.49159, 0.16754, 0.34344, -0.25663, -0.8523, 0.1661, 0.40102, 1.1685, -1.0137, -0.21585, -0.15155, 0.78321, -0.91241, -1.6106, -0.64426, -0.51042]



Embedding-Model



Important

- Select your Embedding Model carefully for your use case
- e.g.
 - intfloat/multilingual-e5-large-instruct ~ 50 %
 - T-Systems-onsite/german-roberta-sentence-transformer-v2 < 70 %
 - danielheinz/e5-base-sts-en-de > 80 %
- Maybe fine-tuning of the embedding model might be an option
- As of now: Treat embedding models as exchangeable commodities!

Recap Embeddings

- Embedding model: “Analog to digital converter for text”
- Embeds the high-dimensional natural language meaning into a lower dimensional-space (the model’s ‘brain’)
- No magic, just applied mathematics
- Math. representation: Vector of n dimensions
- Technical representation: array of floating point numbers

DEMO

Embeddings

Sentence Transformers, local embedding model

Indexing

Introduction

Embeddings

Vector-DBs

Indexing

Retrieval

Indexing II

RAG









Indexing

- Loading
- Clean-up
- Splitting
- Embedding
- Storing

Loading

- Import documents from different sources, in different formats
- LangChain has very strong support for loading data
- Support for cleanup
- Support for splitting

Document loaders

 mhtml MHTML is a is used both for emails but also for archived webpag...	 Microsoft Excel The UnstructuredExcelLoader is used to load Microsoft Excel files.
 Microsoft OneDrive Microsoft OneDrive (formerly	 Microsoft OneNote This notebook covers how to load documents from OneNote.
 Microsoft PowerPoint [Microsoft	 Microsoft SharePoint Microsoft SharePoint is a
 Microsoft Word Microsoft Word	 Modern Treasury Modern Treasury simplifies complex

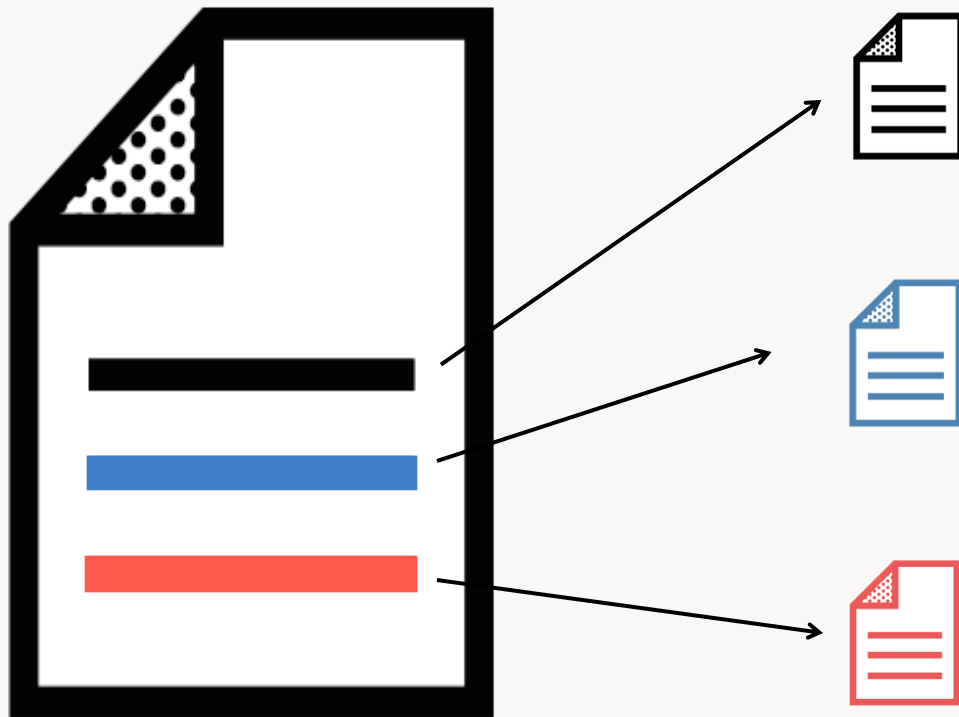
Clean-up

- HTML Tags
- Formatting information
- Normalization
 - lowercasing
 - stemming, lemmatization
 - remove punctuation & stop words
- Enrichment
 - tagging
 - keywords, categories
 - metadata



Splitting (Text Segmentation)

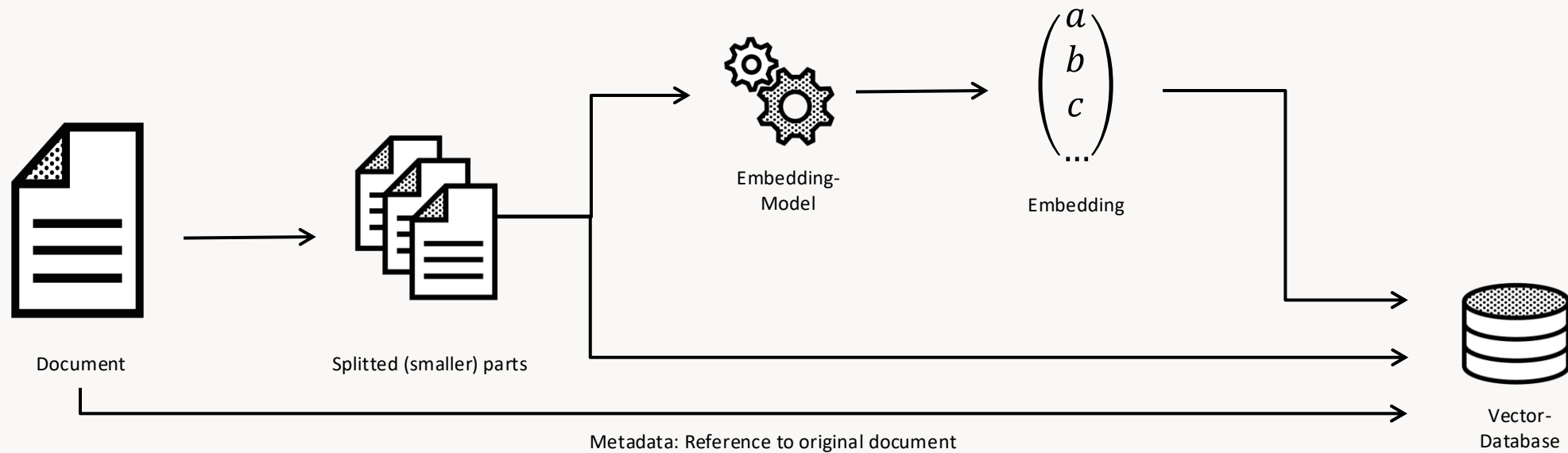
- Document is too large / too much content / not concise enough



- by size (text length)
- by character (`\n\n`)
- by paragraph, sentence, words (until small enough)
- by size (tokens)
- overlapping chunks (token-wise)

Vector-Databases

- Indexing



Retrieval (Search)

Introduction

Embeddings

Vector-DBs

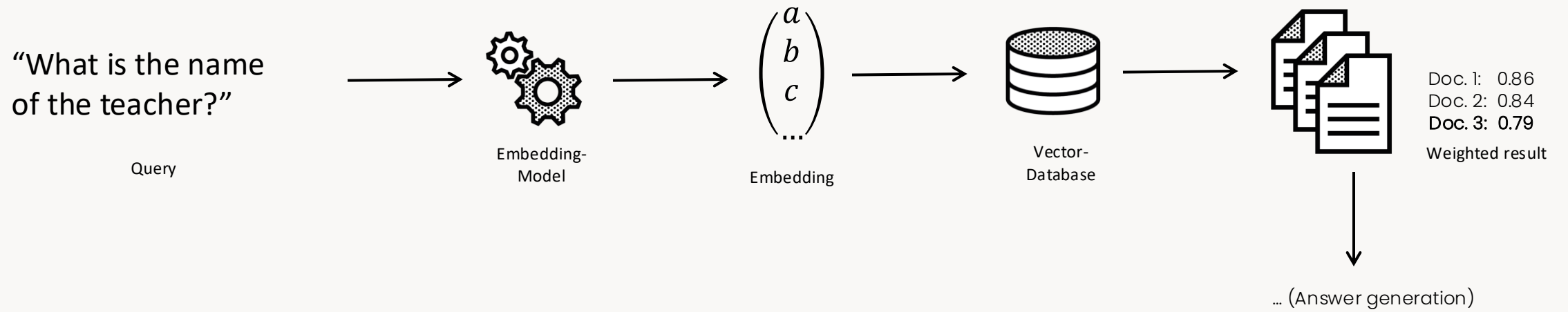
Indexing

Retrieval

Indexing II

RAG

Retrieval



Indexing II

Not good enough?

Introduction

Embeddings

Vector-DBs

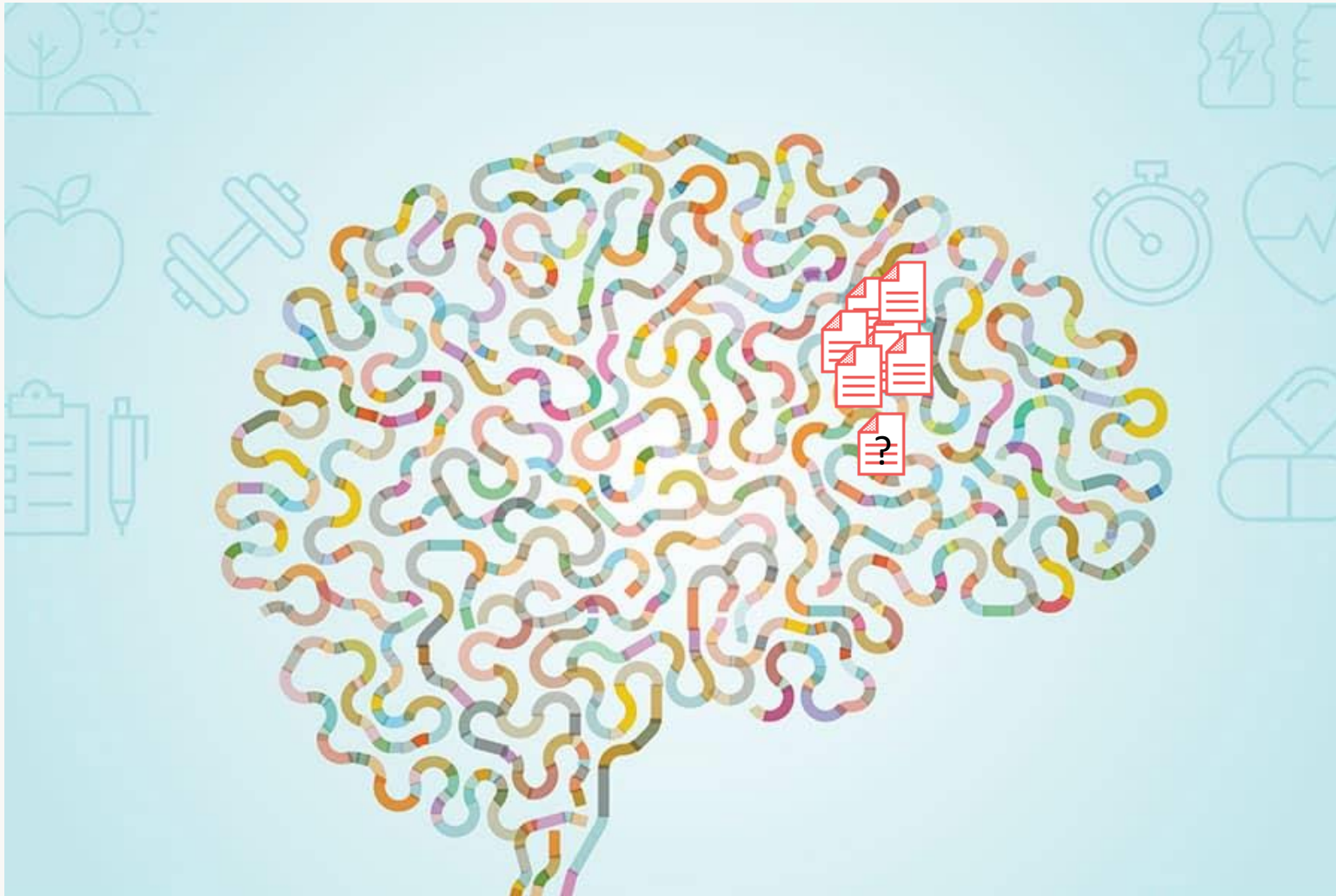
Indexing

Retrieval

Indexing II

RAG

Not good enough?

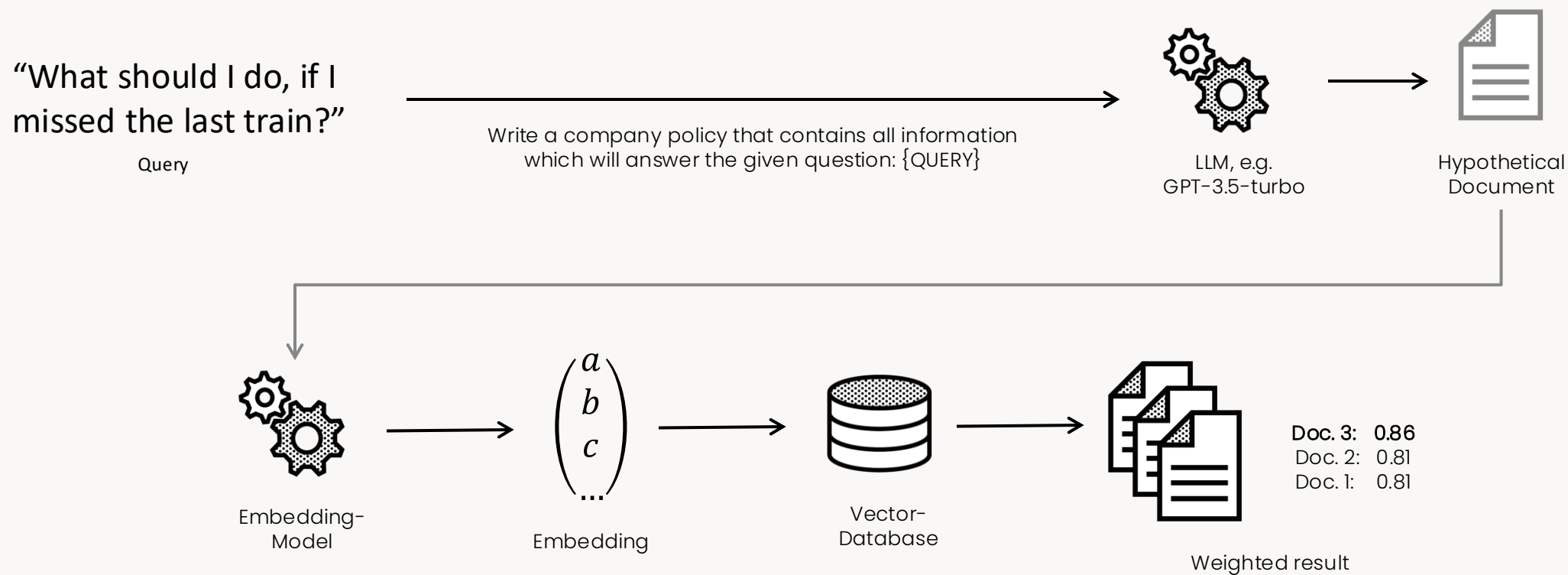


Not good enough?

- Semantic search still only uses your index
- It's just as good as your embeddings
 - All chunks need to be
- Sh*t in, sh*t out

HyDE (Hypothetical Document Embeddings)

■ Search for a hypothetical Document

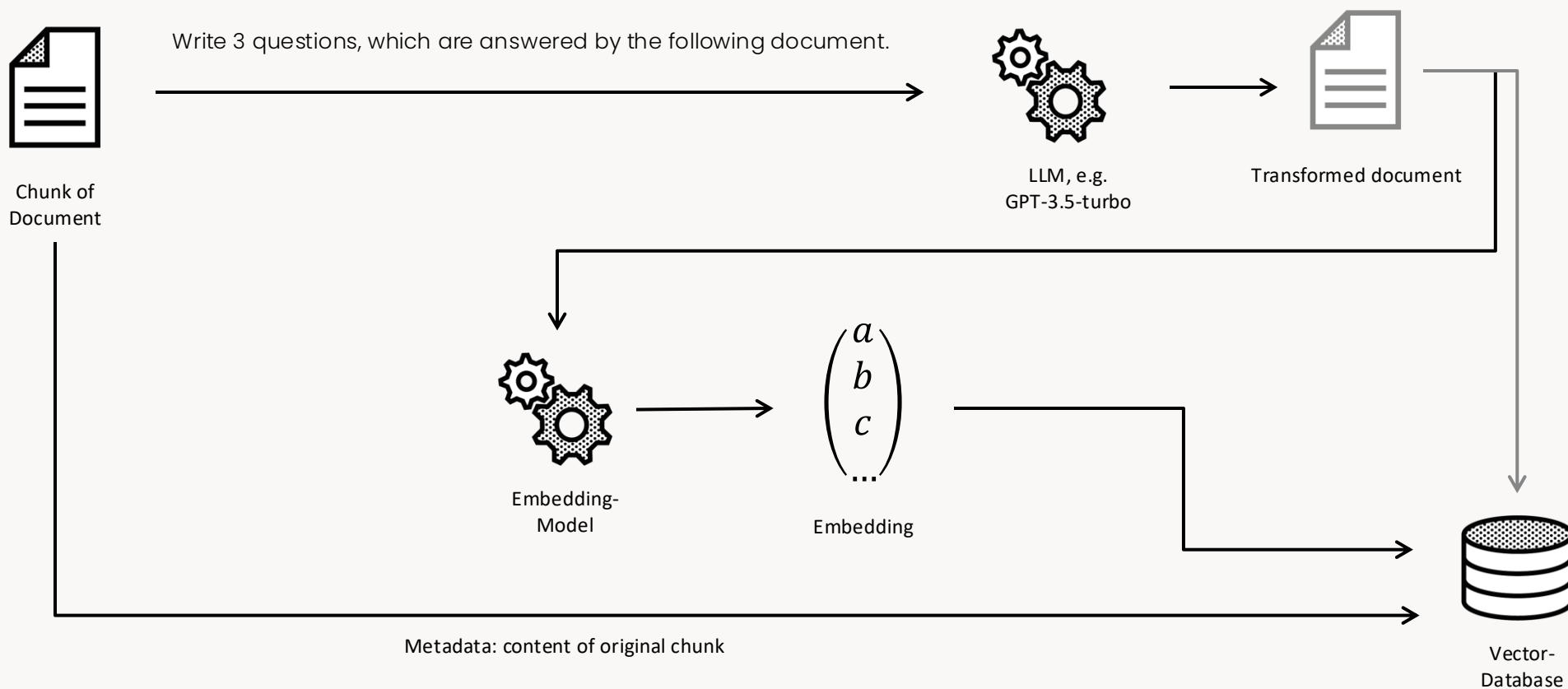


What else?

- Downside of HyDE:
 - Each request needs to be transformed through an LLM (slow & expensive)
 - A lot of requests will probably be very similar to each other
 - Each time a different hyp. document is generated, even for an extremely similar request
 - Leads to very different results each time
- Idea: Alternative indexing
 - Transform the document, not the query

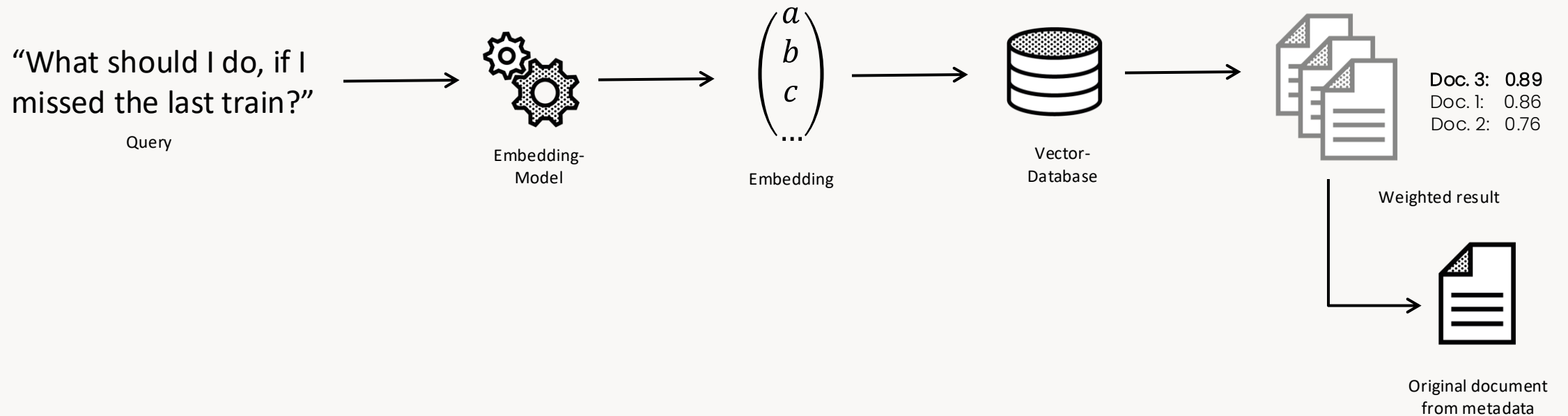
Alternative Indexing

HyQE: Hypothetical Question Embedding



Alternative Indexing

- Retrieval



DEMO

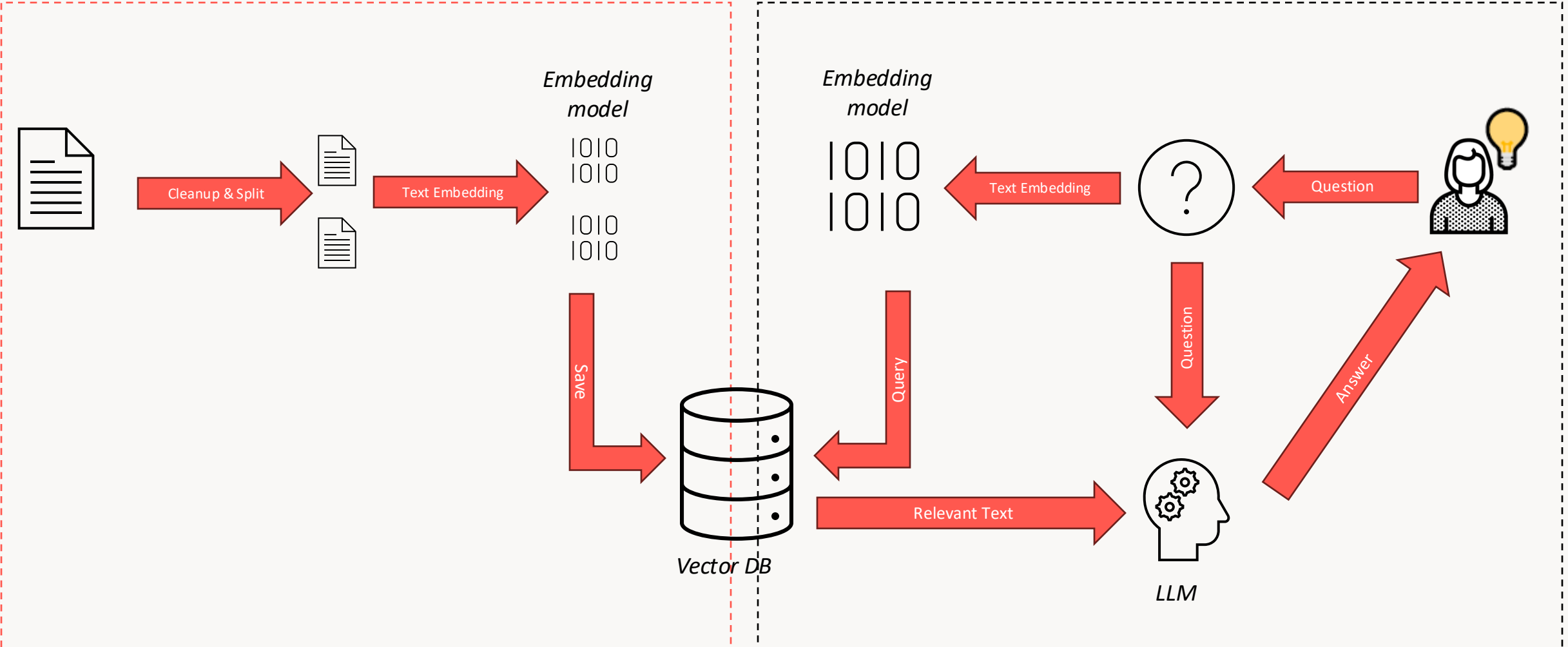
Compare embeddings

LangChain, Qdrant, OpenAI GPT

Conclusion

Retrieval-augmented generation (RAG)

Indexing & (Semantic) search

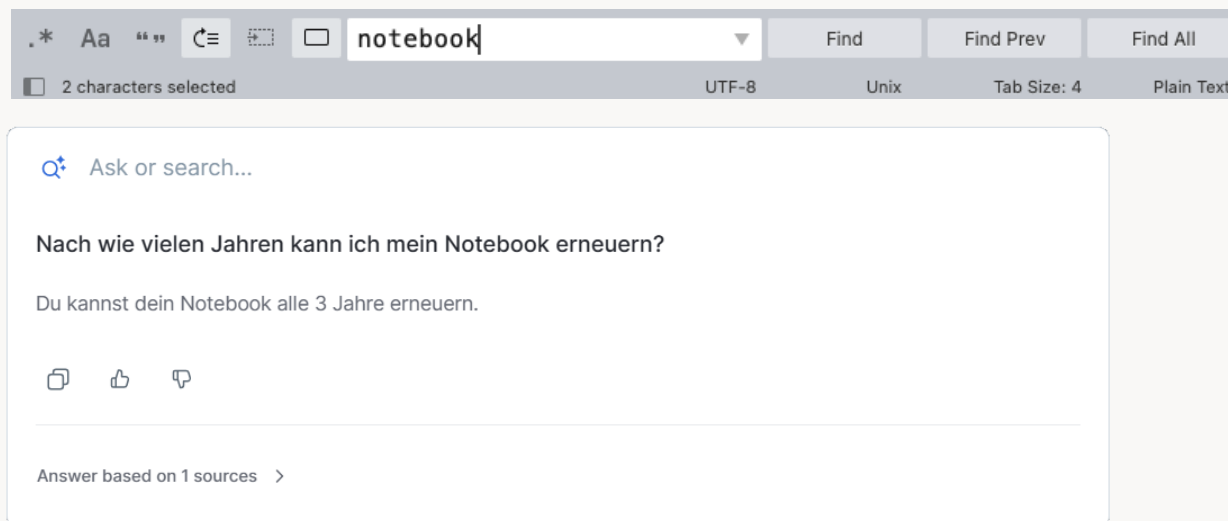


Recap: Not good enough?

- Tune text cleanup, segmentation, splitting
- HyDE or HyQE or alternative indexing
 - How many questions?
 - With or without summary
- Other approaches
 - Only generate summary
 - Extract “Intent” from user input and search by that
 - Transform document and query to a common search embedding
 - HyKSS: Hybrid Keyword and Semantic Search
<https://www.deg.byu.edu/papers/HyKSS.pdf>
- Always evaluate approaches with your own data & queries
- The actual / final approach is more involved as it seems on the first glance

Conclusion

- Semantic search is a first and fast Generative AI business use-case
- Quality of results depend heavily on data quality and preparation pipeline
- RAG pattern can produce breathtaking good results without the need for user training



Thank you!

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Demos:

<https://github.com/thinktecture-labs/genai-engineering-days-2024-talk-to-your-data>

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<https://thinktecture.com/sebastian-gingter>

“Talk to your Data”: Improving RAG solutions based on real-world experiences



Slides & Code

<https://www.thinktecture.com/de/sebastian-gingter>

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