NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

NTU Academy for Professional and Continuing Education

(SCTP) Advanced Professional Certificate

Data Science and AI

NANYANG
TECHNOLOGICAL
UNIVERSITY
SINGAPORE

3.9 Natural Language Processing

Module Overview

3.1 Probability and Statistics for Machine Learning

3.2 Introduction to Machine Learning

3.3 Supervised Learning

3.4 Supervised Learning - Advanced

3.5 Unsupervised Learning

3.6 Time Series Data & Forecasting

3.7 Neural Network & Deep Learning

3.8 Computer Vision (CV)

3.9 Natural Language Processing (NLP)

3.10 NLP - Advanced

Lesson Objectives

- Text Preprocessing
- Text Representations
- Vector Space Model and Word Embeddings
- Text Classification

Garfield was trying to stay cool

Why do we need NLP?

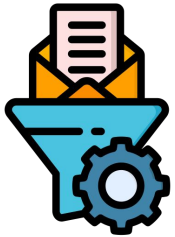
1. Makes Technology Understandable

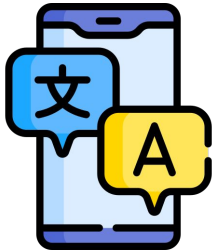
NLP enables machines to understand, interpret, and respond to human language — whether written or spoken. This is what powers voice assistants (like Siri or Alexa), chatbots, and automated customer service.

2. Drives Automation

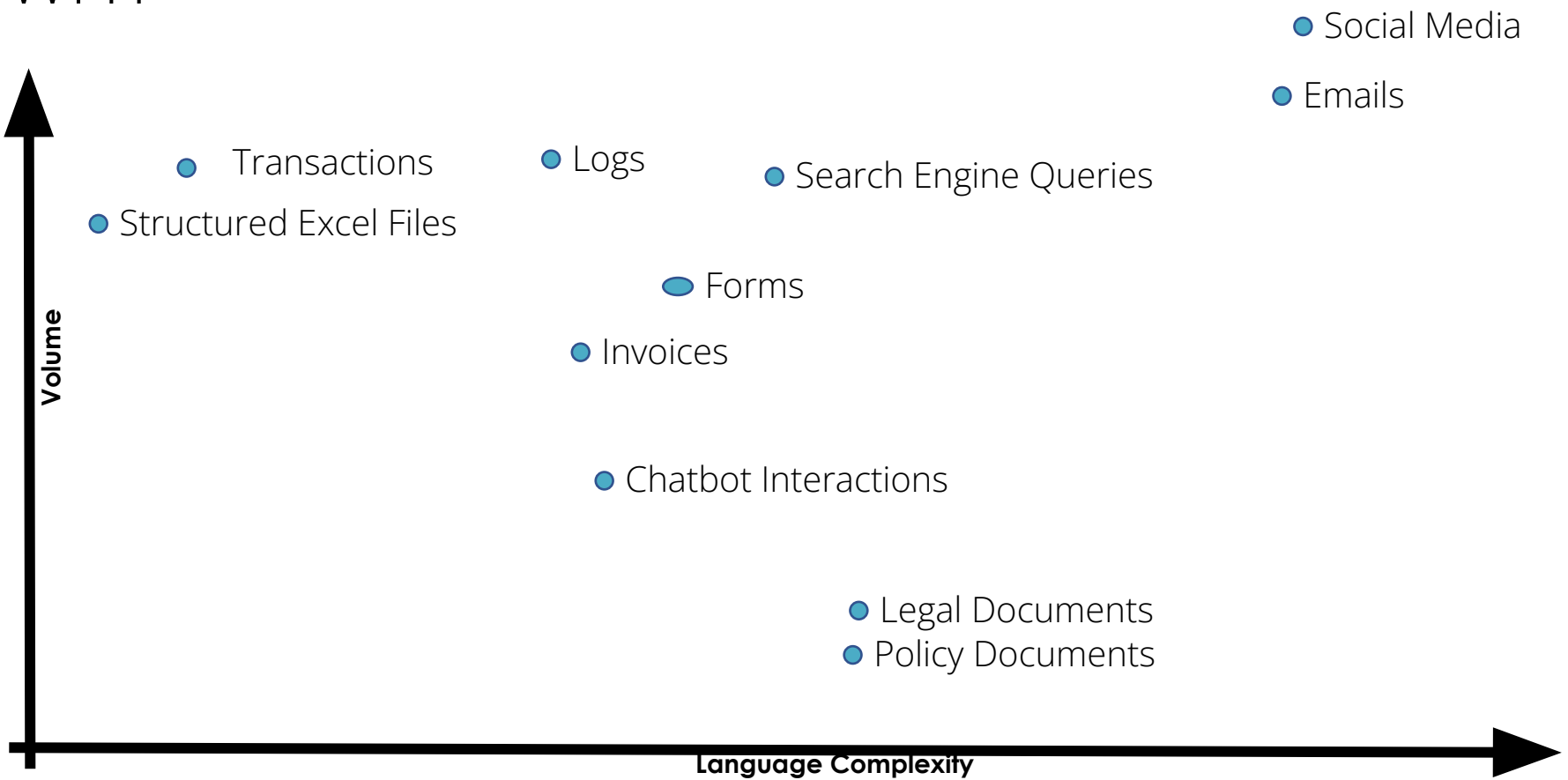
NLP automates tasks that would otherwise require human input:

- Email filtering
- Document summarization
- Language translation
- Sentiment analysis (e.g., understanding customer feedback)

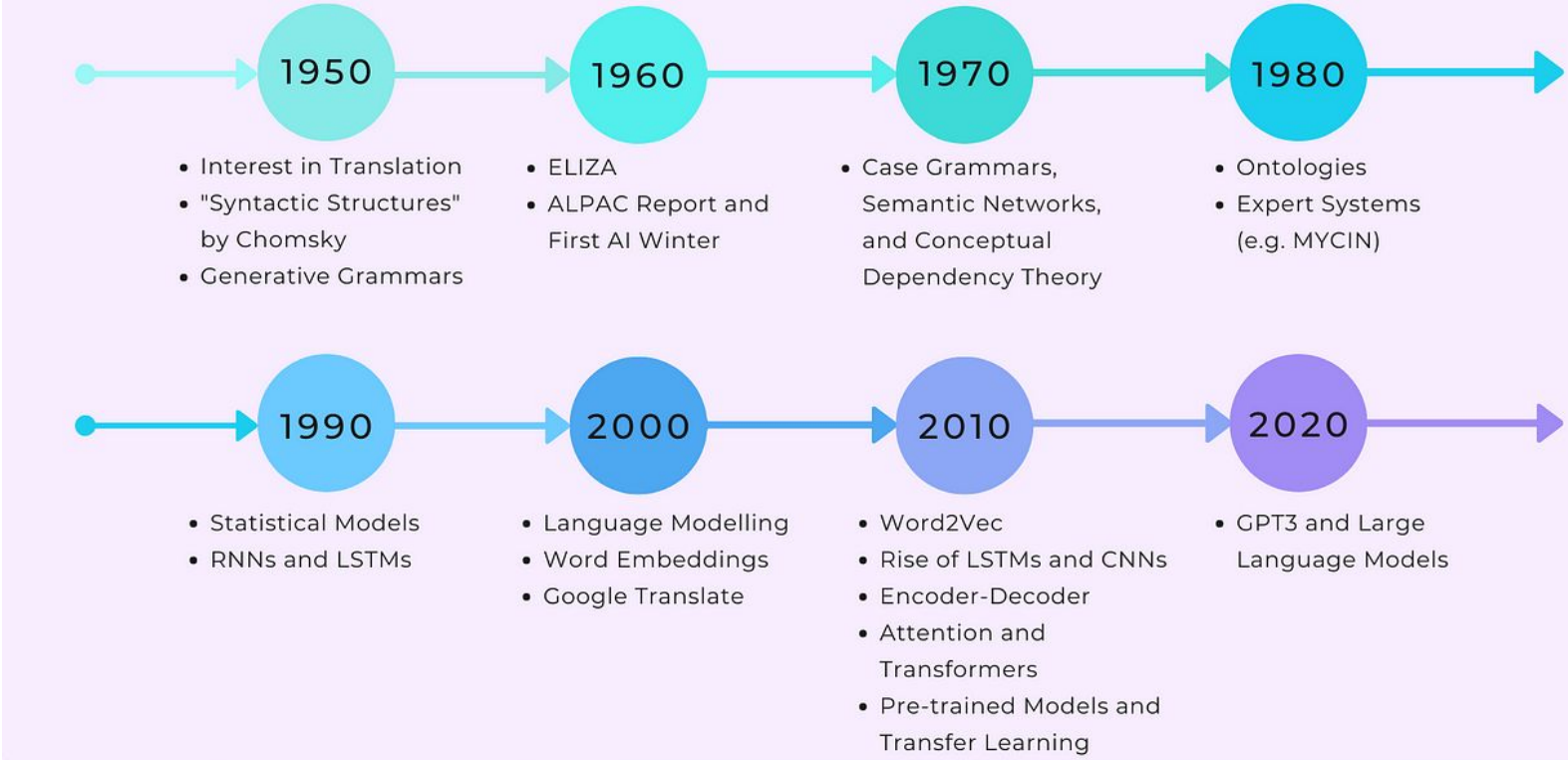




WHY



A Brief Timeline of NLP



https://medium.com/nlplanet/a-brief-timeline-of-nlp-bc45b640f07d

```
  Welcome to
                    EEEEEE  LL      IIII   ZZZZZZ   AAAAA
                    EE      LL       II       ZZ   AA   AA
                    EEEEE   LL       II     ZZZ    AAAAAAA
                    EE      LL       II    ZZ      AA   AA
                    EEEEEE  LLLLLL  IIII ZZZZZZ    AA   AA

  Eliza is a mock Rogerian psychotherapist.
  The original program was described by Joseph Weizenbaum in 1966.
  This implementation by Norbert Landsteiner 2005.


ELIZA: Is something troubling you ?
YOU:   Men are all alike.
ELIZA: What is the connection, do you suppose ?
YOU:   They're always bugging us about something or other.
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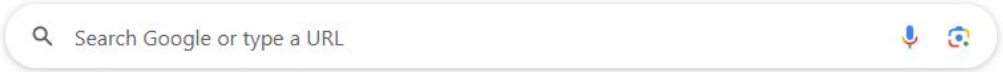
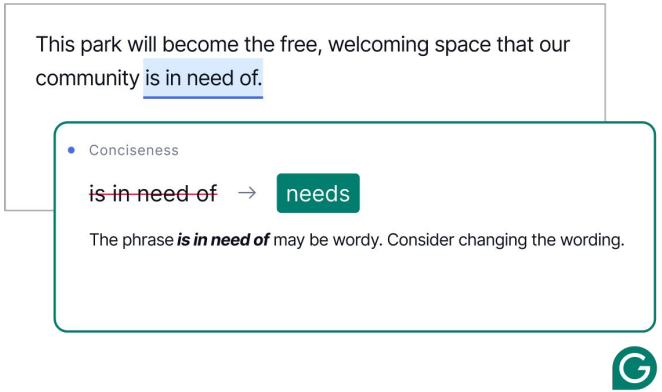
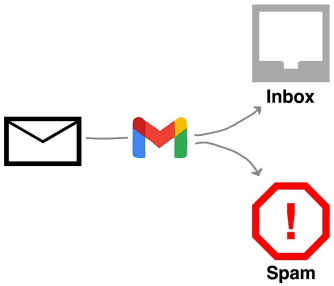
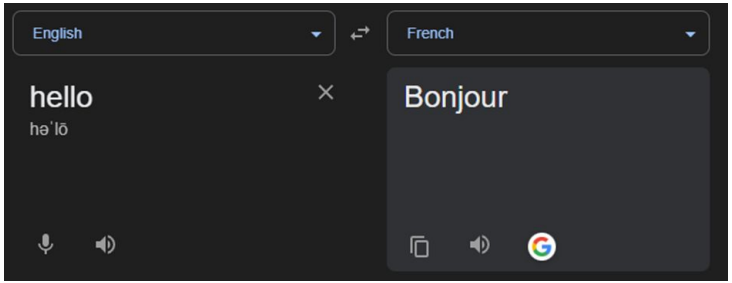
ELIZA: Is it important to you that your boyfriend made you come here ?
YOU:   He says I'm depressed much of the time.
ELIZA: I am sorry to hear that you are depressed.
YOU:   It's true. I am unhappy.
ELIZA: Can you explain what made you unhappy ?
YOU:
```

NLP in real life





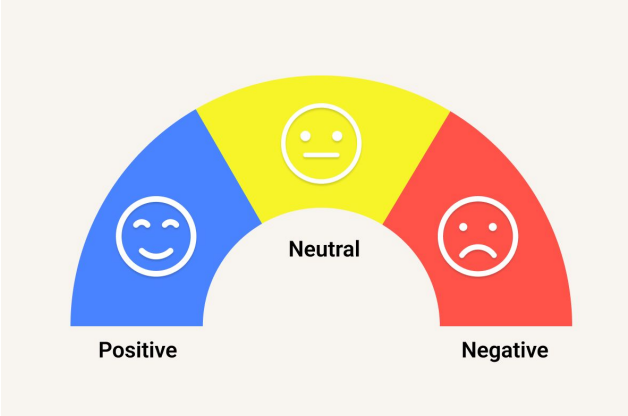




https://www.grammarly.com/blog/company/transforming-writing-style-with-ai/

NLP Applications

- **Text Classification**: Assigning categories or labels to text, such as spam detection in email services.
- **Machine Translation**: Translating text from one language to another, like Google Translate.
- **Sentiment Analysis**: Identifying the sentiment of text, used in social media monitoring and market research.
- **Chatbots and Virtual Assistants**: Powering conversational agents like Siri, Alexa, and customer service bots.
- **Information Extraction**: Extracting structured information from unstructured text, such as named entity recognition.
- **Summarization**: Generating a shortened version of a text, retaining its most important information.
- **Speech Recognition**: Translating spoken language into text, used in voice user interfaces.
- **Question Answering**: Building systems that automatically answer questions posed by humans in a natural language (ChatGPT).




```
  Welcome to
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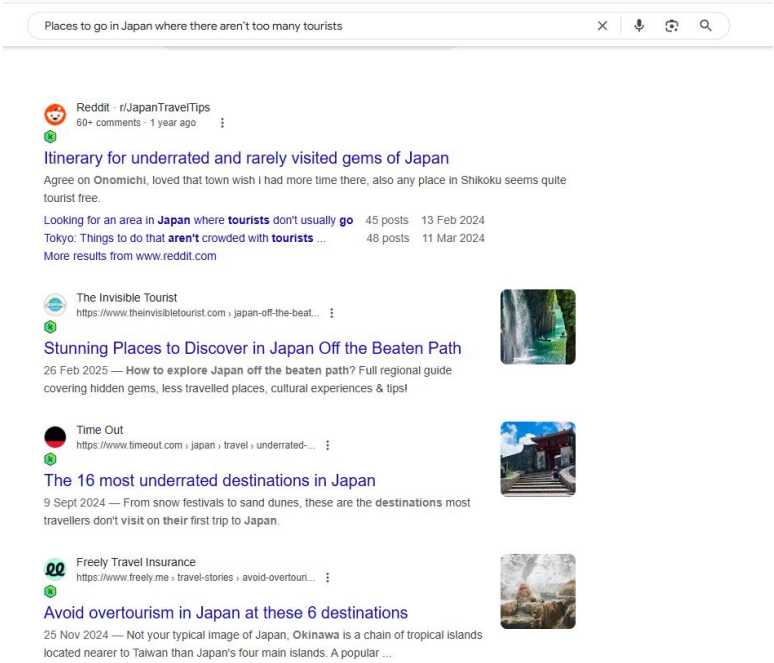
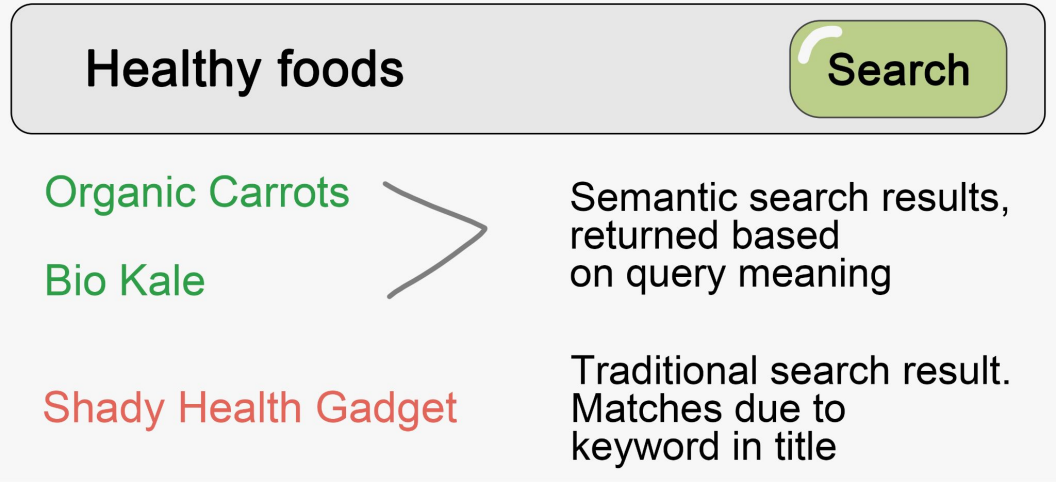
Try Eliza - https://www.masswerk.at/elizabot/eliza.html

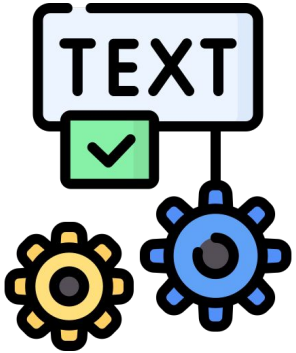
NLP Applications - Semantic Search Engine





Text Processing

Text preprocessing is a critical step in NLP. It involves preparing and cleaning text data for further analysis and modeling. The goal is to simplify the text and remove any noise that might distract the machine learning algorithms from understanding the core content.



Raw text data is often messy and unstructured, with various issues:

- Irrelevant characters and symbols
- Inconsistent formatting
- Typos and spelling errors
- Diverse languages and slang
- Stopwords (commonly used words that may not be useful in analysis)

Tokenisation

Tokenization is the process of splitting text into smaller units called tokens.
These tokens can be:

- White Space (e.g. "I love cats" → ["I", "love", "cats"])
- Characters (e.g. "Hi" → ["H", "i"])
- Sentences (splitting a paragraph into sentences)

It’s one of the first steps in text processing for most NLP pipelines.

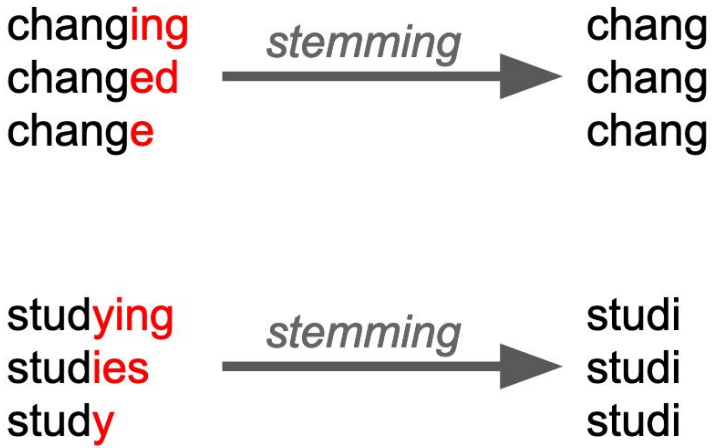
Stemming

Stemming removes suffixes (and sometimes prefixes) from words to arrive at the stem, which may not always be a valid word in the language.

For example:

- `"running"` → `"run"`
- `"flies"` → `"fli"`
- `"happiness"` → `"happi"`

Note: The resulting stem might not be a real word! Stemming is rule-based, not always linguistically correct.



Lemmatization

Lemmatization is the process of grouping together the inflected forms of a word so they can be analyzed as a single item, identified by the word's lemma, or dictionary form.

While stemming often involves rule-based chopping of ends of words, lemmatization involves a linguistic approach to reduce a word to its base or root form. Lemmatization uses vocabulary and morphological analysis, often with the aid of part-of-speech tagging, to return the base or dictionary form of a word, known as the lemma.

Word	Lemma	Stemmed
running	run	run
better	good	better
studies	study	studi
was	be	wa

Stop Words

Stop words are the most frequently used words in a language that usually carry grammatical meaning but not much semantic value.

Examples (in English):

the, is, in, at, which, on, a, an, and, but

For instance, in the sentence:

`“The cat is on the mat”`

After stop word removal → `"cat mat"`

Removing stop words can help:

- Reduce noise in the data
- Improve performance of models by reducing dimensionality
- Focus on meaningful content (like nouns, verbs, key adjectives)
- However, it's not always beneficial—especially if word context or sentiment matters.

Part of Speech Tagging

Part-of-Speech tagging assigns tags (e.g., noun, verb, adjective) to each word in a text based on:

- Its definition
- Its context within the sentence

For example:

> **Sentence:** `"She **can** fish."`
> **Tags:** `She`/PRP (pronoun), `can`/MD (modal verb), `fish`/VB (verb)

Now compare:

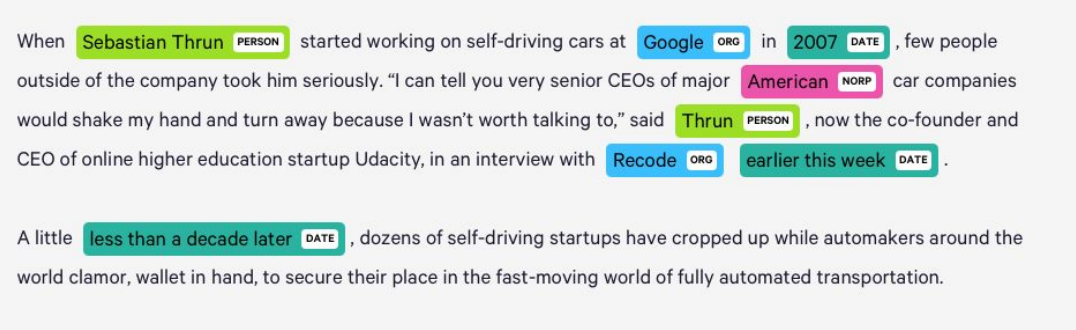
> **Sentence:** `"I caught a **can** of tuna."`
> **Tags:** `I`/PRP, `caught`/VBD, `a`/DT, `can`/NN (noun), `of`/IN, `tuna`/NN

Same word, different tag depending on context!

Why we need POS tagging

It helps NLP systems understand the structure and meaning of text:

- **Named Entity Recognition (NER):** Distinguish between `"Apple"` as a noun vs. brand.
- **Text-to-speech:** Correct pronunciation (e.g., `"read"` as past or present).
- **Machine translation:** Proper grammar conversion.
- **Dependency parsing:** Understand relationships between words.



https://demos.explosion.ai/displacy-ent

Code-along

Jupyter Notebook

Part 1: Text Processing

Language Models

A language model predicts the likelihood of a sequence of words.

> “Given the previous words, what’s the most probable next word?”

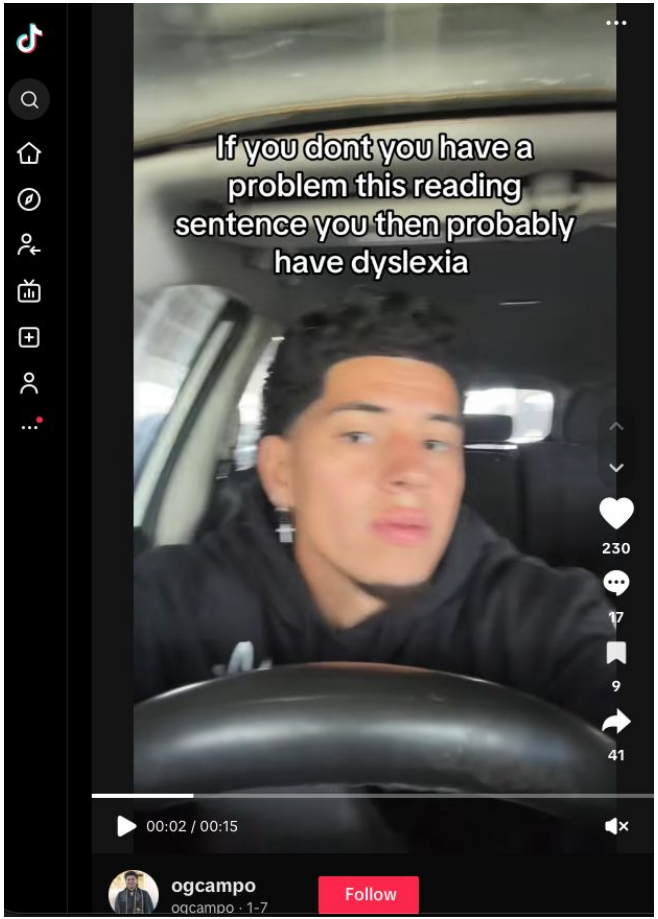
For the sentence:

> `“The cat sat on the ___”`

A language model might rank:

- `"mat"` → high probability
- `"refrigerator"` → lower
- `"banana"` → very low

The model has learned grammar, semantics, and word patterns.



Types of Language Models

Type	How it works	Example
N-gram	Uses fixed-size history (e.g., last 2 words)	`"The cat"` → predicts `"sat"`
RNN/LSTM	Learns longer-term dependencies using hidden states	Captures sequences and context better than N-grams
Transformer -based	Uses attention to look at all words at once (no fixed memory)	BERT, GPT, etc.

N grams

An n-gram is a sequence of n words (or tokens) in a text.
They're used to model word sequences and estimate how likely a word is to follow others.

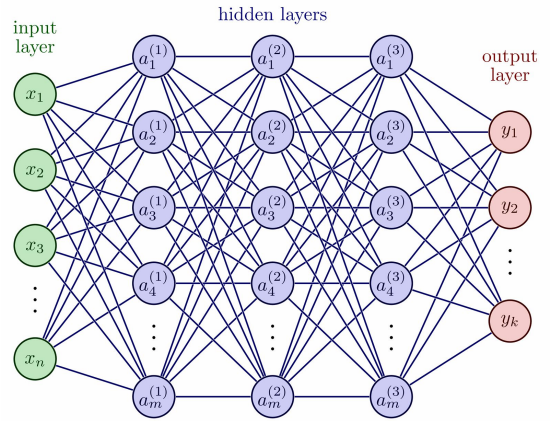
N grams

N-grams are now mostly replaced by neural language models (like RNNs and Transformers) that:

- Capture long-term dependencies
- Handle out-of-vocabulary words better
- Use attention to model context dynamically

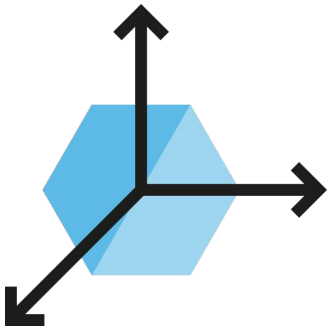
BUT — n-grams are still useful for:

- Spell-checkers
- Query completion
- Simpler tasks or when interpretability is needed



Vector Space Model

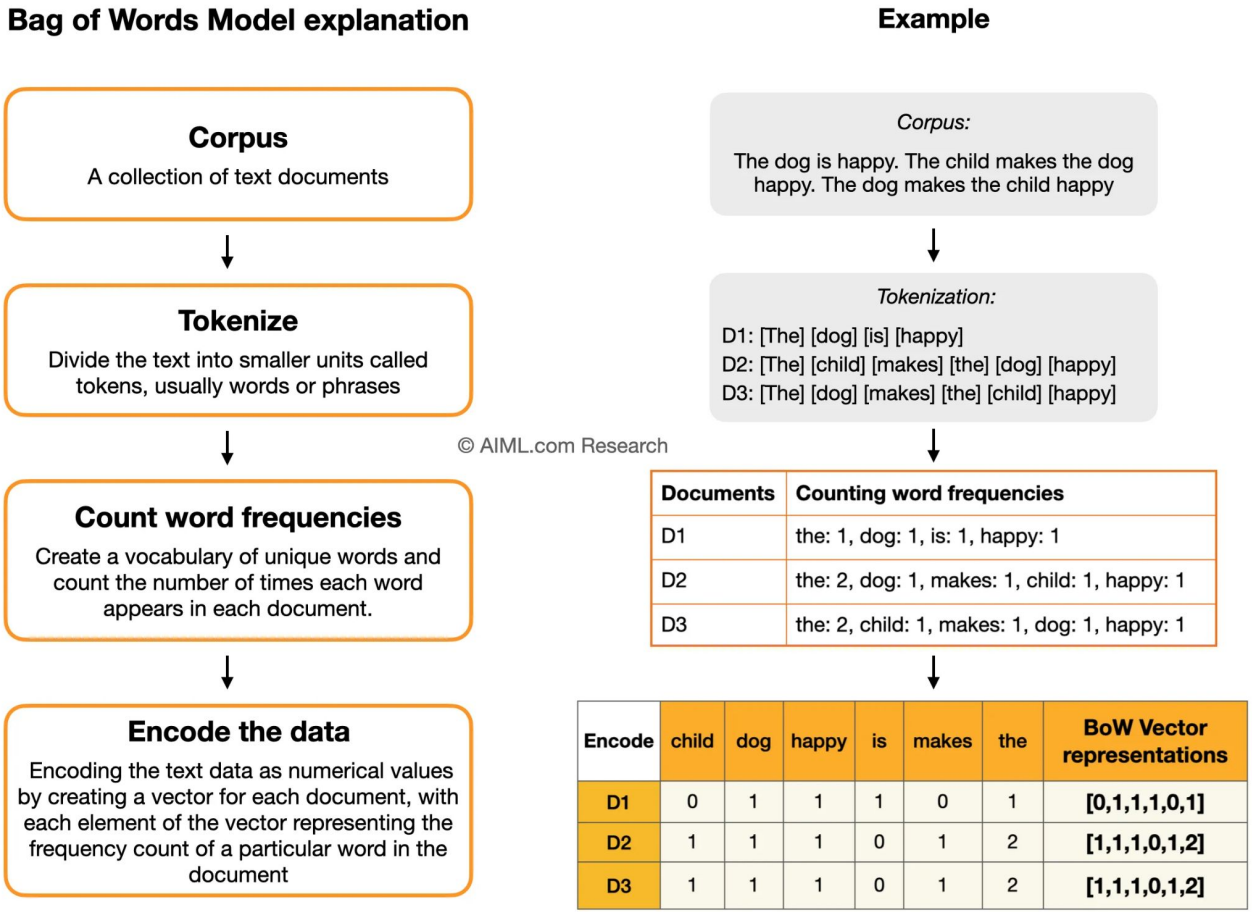
The Vector Space Model (VSM) is a mathematical model used to represent text documents as vectors of identifiers, such as index terms. It is used in information retrieval and text mining to measure the similarity between documents. In VSM, each dimension corresponds to a separate term, and the value in each dimension represents the significance of the term in the document.



Term-Document Matrix

In VSM, a Term-Document Matrix is a mathematical representation of a text corpus. It describes the frequency of terms that occur in the collection of documents. In a Term-Document Matrix, rows correspond to terms in the corpus while columns correspond to documents. Each entry in this matrix denotes the frequency or the weight of a term in a document.

Bag of Words Model



Documents	Counting word frequencies
D1	the: 1, dog: 1, is: 1, happy: 1
D2	the: 2, dog: 1, makes: 1, child: 1, happy: 1
D3	the: 2, child: 1, makes: 1, dog: 1, happy: 1

Encode	child	dog	happy	is	makes	the	BoW Vector representations
D1	0	1	1	1	0	1	[0,1,1,1,0,1]
D2	1	1	1	0	1	2	[1,1,1,0,1,2]
D3	1	1	1	0	1	2	[1,1,1,0,1,2]

https://aiml.com/what-is-bag-of-words-model/

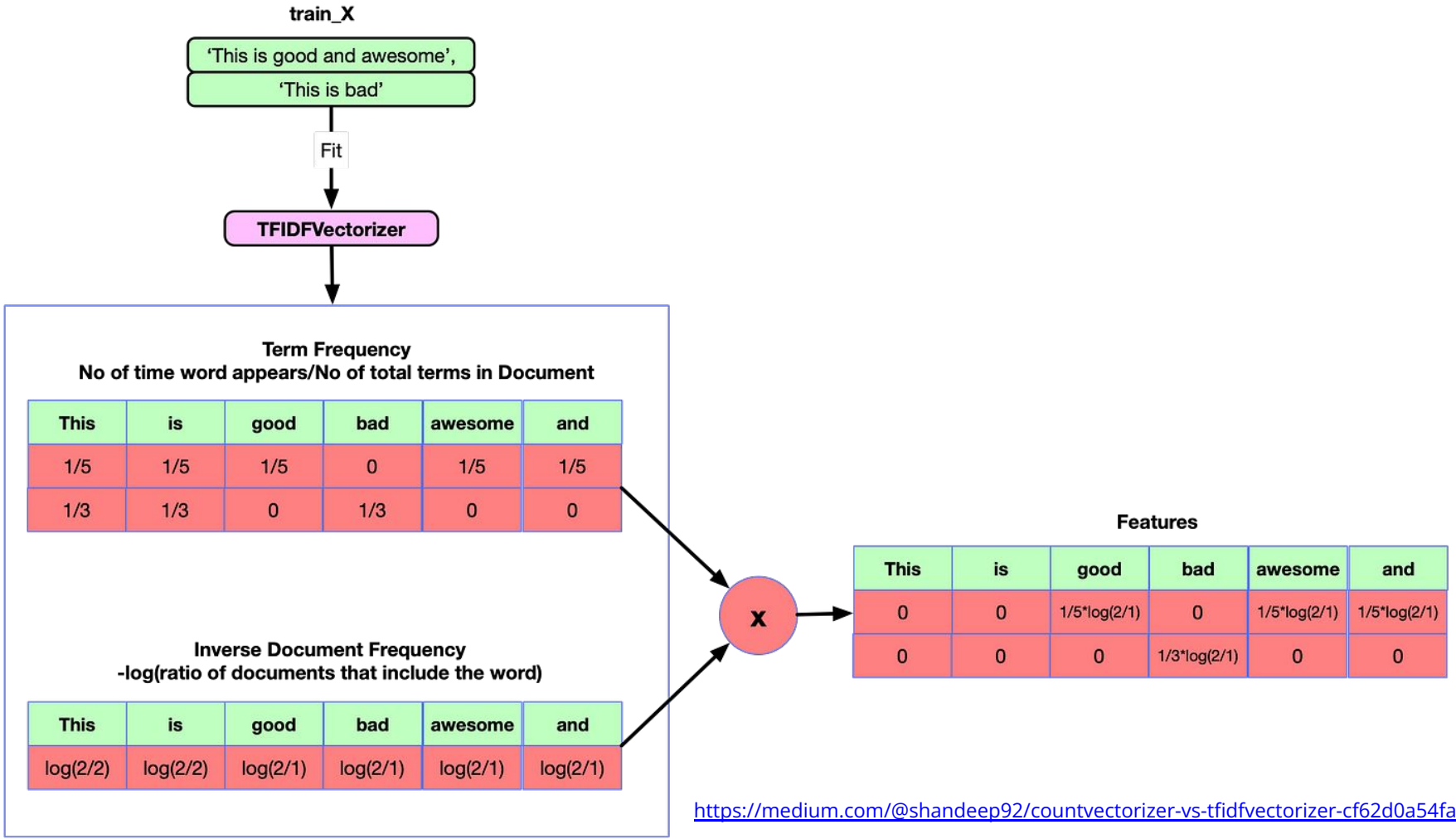
TF-IDF

Converts a collection of text into a matrix of features (like CountVectorizer), but it applies a weighting scheme to the word counts.

- **TF** (Term Frequency): How often a word appears in a document.
- **IDF** (Inverse Document Frequency): Measures how important a word is across all documents, with rare words given more weight.

$$\text{TF}(t, d) = \frac{\text{Number of times term t appears in document d}}{\text{Total number of terms in document d}}$$

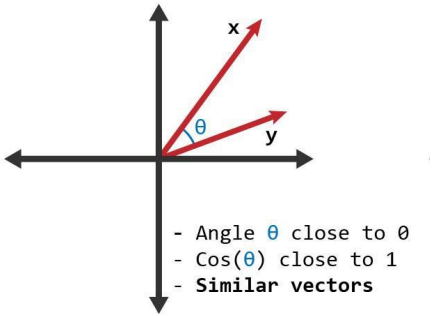
$$\text{IDF}(t, D) = \log \frac{\text{Total number of documents in corpus D}}{\text{Number of documents containing term t}}$$

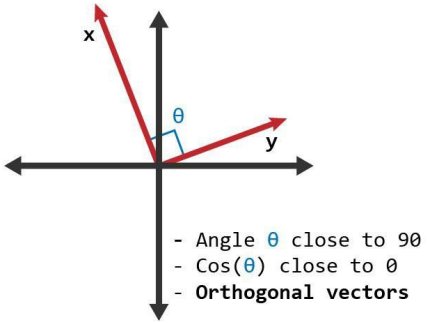


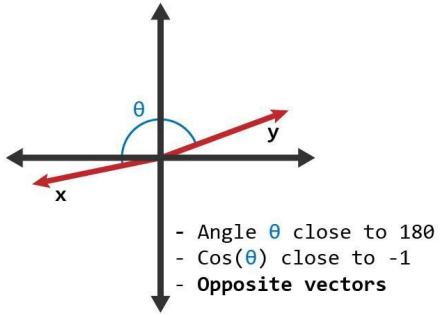
https://medium.com/@shandeep92/countvectorizer-vs-tfidfvectorizer-cf62d0a54fa4

Text Similarity - Cosine Similarity

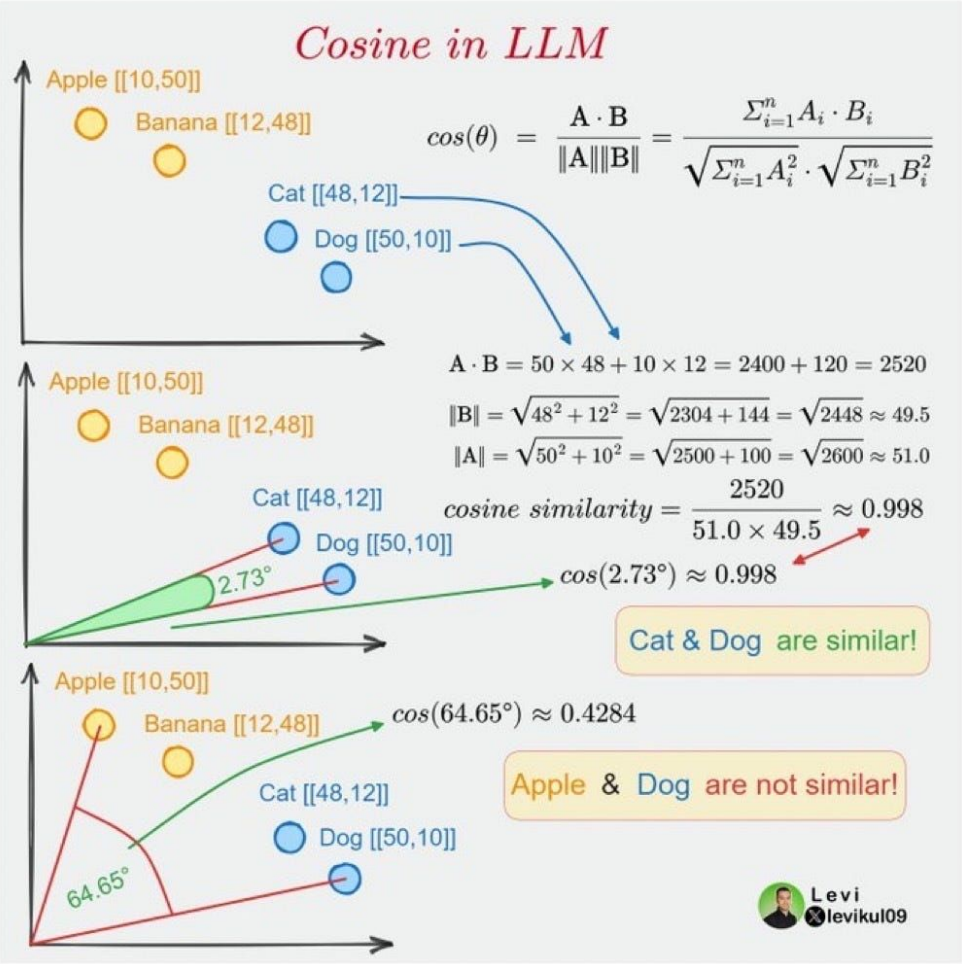
- Cosine similarity measures the cosine of the angle between two vectors in an n-dimensional space.
- Think of each word, sentence, or document as a vector, and cosine similarity tells you how similar their directions are — regardless of their magnitude (length).
- In NLP, cosine similarity typically falls between 0 and 1 because vector values are usually non-negative.







Text Similarity - Cosine Similarity

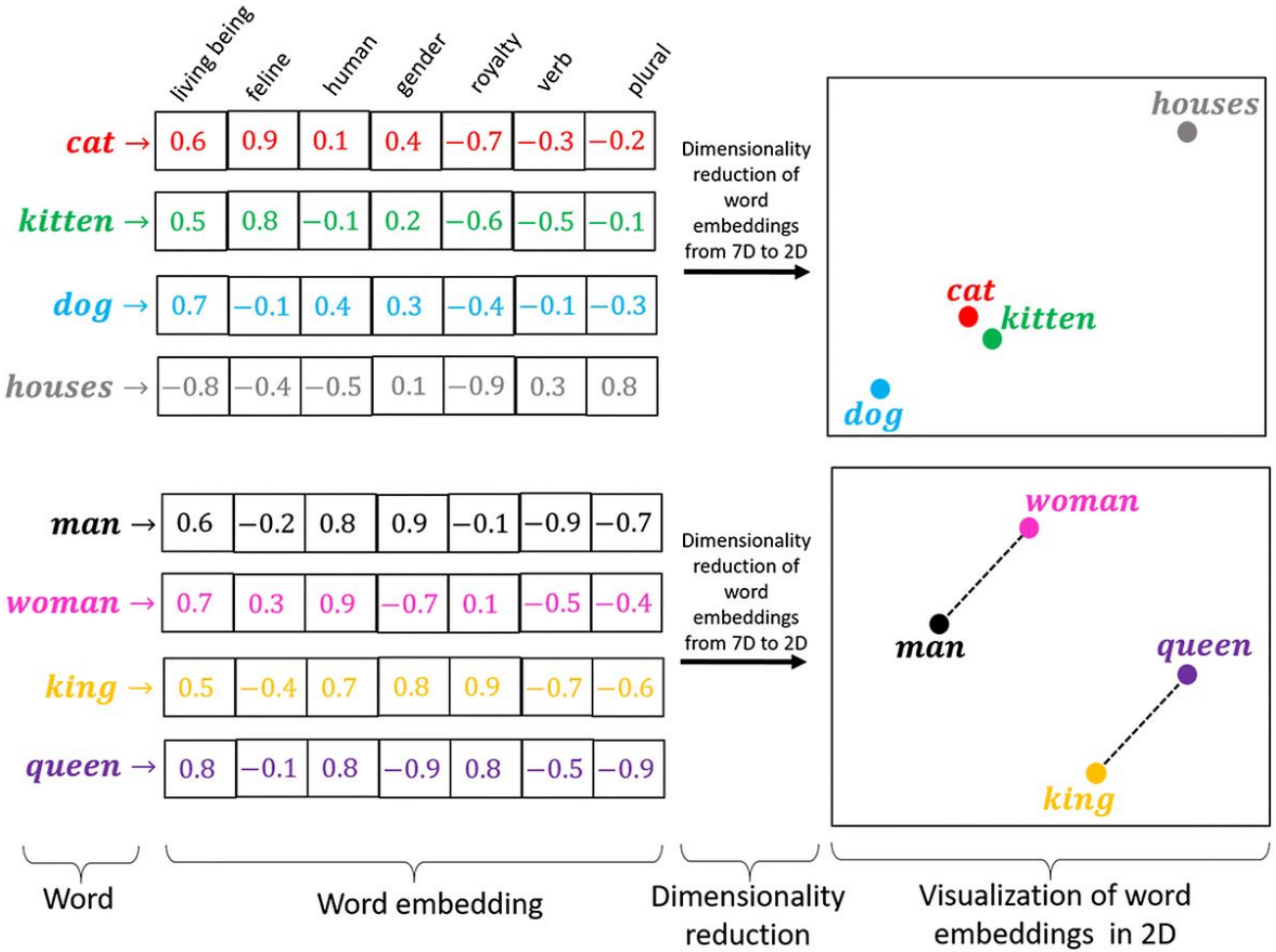


Code-along

Jupyter Notebook

Part 2: TF-IDF Vectorizer

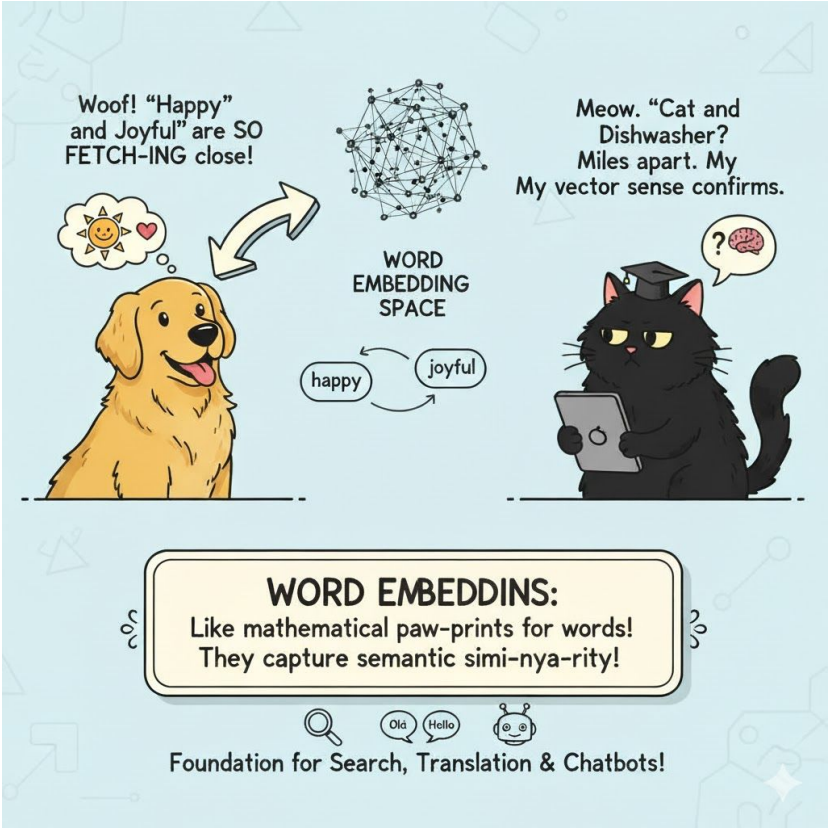
Word Embeddings



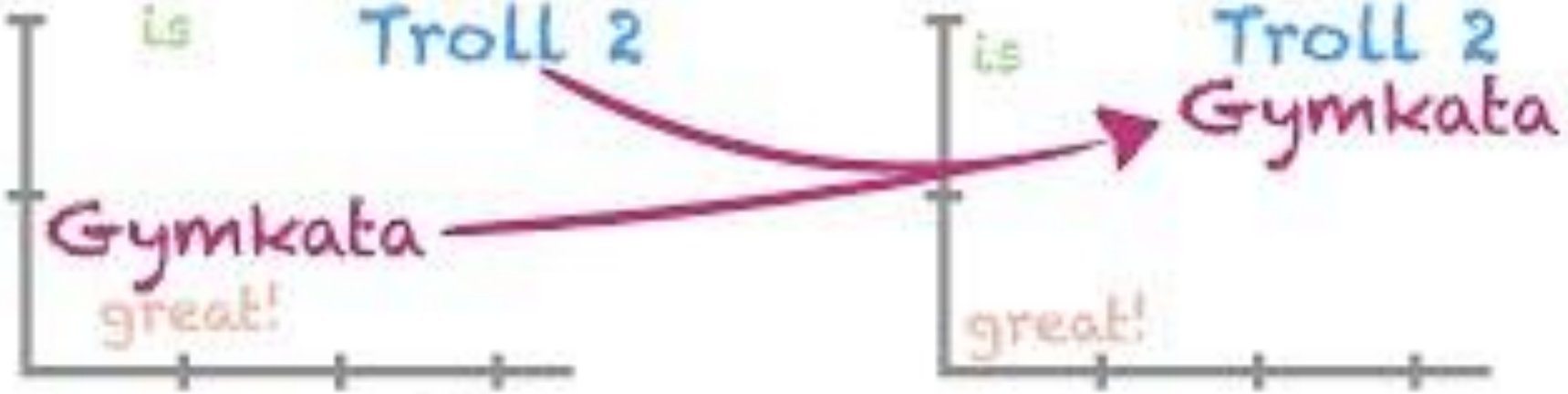
Word Embeddings

They’re like mathematical fingerprints for words. Each word is mapped to a vector (e.g., 300 dimensions) where semantic relationships between words are captured by the distance and direction between their vectors.

- Capture semantic similarity: “happy” and “joyful” will be close in vector space.
- Input for models like classifiers, clustering algorithms, or neural networks.
- Foundation for tasks like sentiment analysis, machine translation, chatbots, search, and more.



Word Embedding and Word2Vec...



...Clearly Explained!!!

https://www.youtube.com/watch?v=viZrOnJclY0&t=1s

Word Embeddings

Feature	Word2Vec	GloVe	FastText	BERT
Embedding type	Static	Static	Static	Contextual
Handles OOV words?	No	No	Yes	Yes
Subword aware?	No	No	Yes	Yes
Dimensionality	100–300	50–300	100–300	768 (base), 1024 (large)

Code-along

Jupyter Notebook

Part 3: Word Embeddings

End of Lesson - Exit Ticket

Survey Link

https://www.slido.com