1. What is Word Embedding?

Definition (Technical):
Word embedding is a method of representing words as **numerical vectors** in a continuous vector space, where words with similar meanings are located close to each other.

Instead of representing words as **one-hot vectors** (sparse and high-dimensional), embeddings give us **dense, low-dimensional vectors** that capture **semantic meaning**.

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2. Why We Need Word Embeddings

Before embeddings, the common method was **one-hot encoding**:

- If you have a vocabulary of 10,000 words, each word is represented as a **10,000-dimensional vector** with only one "1" and the rest "0"s.
- Problems:
    1. **No semantic meaning**: “Cat” and “Dog” are as far apart as “Cat” and “Car”.
    2. **High dimensionality**: Inefficient storage and computation.
    3. **Sparse representation**: Most values are zero → waste of space.

Word embeddings solve this by:

- Compressing to smaller dimensions (e.g., 300D instead of 10,000D).
- Making similar words **numerically close** in vector space.
- Allowing models to **learn meaning** from context.

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3. Example of Word Embedding

Let’s say we train an embedding model (like Word2Vec, GloVe, or FastText) and get these 3D representations (for illustration; real ones are usually 100–300D):

Word	Embedding Vector
Cat	[0.21, 0.58, 0.35]
Dog	[0.20, 0.60, 0.33]
Car	[0.91, 0.11, 0.56]

Observation:

- Distance between **Cat** and **Dog** is small → meaning is similar (both are animals).
- Distance between **Cat** and **Car** is large → meaning is unrelated.

Cool property:
Some embeddings capture analogies, e.g.:

$$\text{Vector}(''King'') - \text{Vector}(''Man'') + \text{Vector}(''Woman'') \approx \text{Vector}(''Queen'')$$

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4. Why This Helps Models

When models receive embeddings instead of raw words:

- They can **understand relationships** like synonyms, analogies, and categories.
- They require **less data** to learn meaningful patterns.
- They perform better in **NLP tasks** like sentiment analysis, translation, and question answering.

✅ **In short:**

- **Word Embedding** = compact, meaningful numerical representation of words.
- **Why** = reduces dimensions, captures meaning, improves learning efficiency.
- **Example** = “Cat” and “Dog” vectors are close; “Cat” and “Car” are far apart.