# Foundations of Statistical and Machine Learning for Actuaries -

# Artificial Intelligence, Natural Language Processing, and ChatGPT

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# Schedule

| Day and Time | Presenter | Topics | Notebooks for Participant Activity |
|---|---|---|---|
| Monday Morning | Jed | Welcome and Foundations<br>Hello to Google Colab | Auto Liability Claims |
| | Jed | Classical Regression Modeling | Medical Expenditures (MEPS) |
| Monday Afternoon | Andrés | Regularization, Resampling, Cross-Validation | Seattle House Sales |
| | Andrés | Classification | Victoria road crash data |
| Tuesday Morning | Andrés | Trees, Boosting, Bagging | |
| | Jed | Big Data, Dimension Reduction and Non-Supervised Learning | Big Data, Dimension Reduction, and Non-Supervised Learning |
| Tuesday Afternoon | Jed | Neural Networks | Seattle House Prices<br>Claim Counts |
| | Jed | Graphic Data Neural Networks | MNIST Digits Data |
| Tuesday 4 pm | Fei | Fei Huang Thoughts on Ethics | |
| Wednesday Morning | Jed | Recurrent Neural Networks, Text Data | Insurer Stock Returns |
| | Jed | Artificial Intelligence, Natural Language Processing, and ChatGPT | |
| Wednesday After Lunch | Dani | Dani Bauer Insights | |
| Wednesday Afternoon | Andrés | Applications and Wrap-Up | |

# Wednesday Morning 5B. Artificial Intelligence, Natural Language Processing, and ChatGPT

## Machine Learning

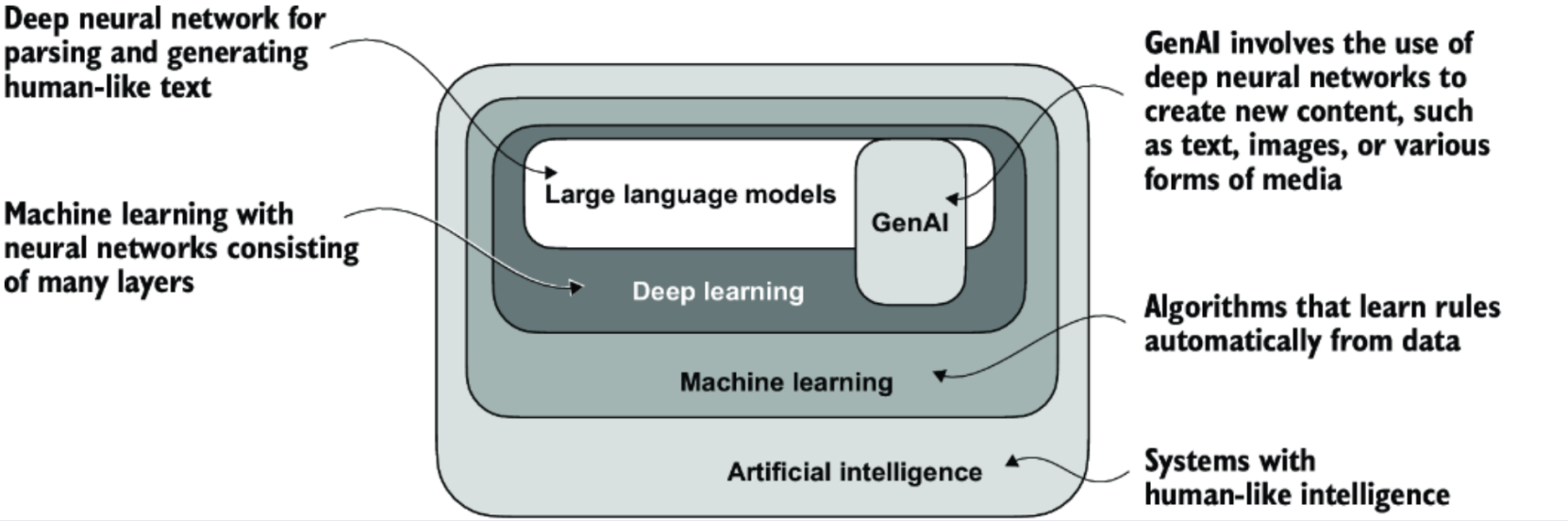
- **Machine learning** involves the development of algorithms that can learn from and make predictions or decisions based on data without being explicitly programmed.
  - To illustrate this, imagine a spam filter as a practical application of machine learning.
  - Instead of manually writing rules to identify spam emails, a machine learning algorithm is fed examples of emails labeled as spam and legitimate emails.
  - By minimizing the error in its predictions on a training dataset, the model then learns to recognize patterns and characteristics indicative of spam, enabling it to classify new emails as either spam or not spam.

## Deep Learning

- **Deep learning** is a subset of machine learning that focuses on utilizing neural networks with three or more layers (also called deep neural networks) to model complex patterns and abstractions in data.
  - In contrast to deep learning, traditional machine learning requires manual feature extraction. This means that human experts need to identify and select the most relevant features for the model.

## The Scope of Artificial Intelligence

- While the field of **AI** is now dominated by machine learning and deep learning, it also includes other approaches—for example, using rule-based systems, genetic algorithms, expert systems, fuzzy logic, or symbolic reasoning.




{ *Credit*: - Build a Large Language Model (From Scratch) }

## A Very Short History of Large Language Models

- 2017: **Transformer architecture** is proposed based on the **self-attention mechanism**, which would then become the de facto architecture for most of the subsequent DL systems (Vaswani et al., 2017);
- 2018: GPT-1 (**G**enerative **P**re-Trained **T**ransformer) for natural language processing with 117 million parameters, starting a series of advances in the so-called **large language models (LLMs)**;
  - 2019: GPT-2 with 1.5 billion parameters;
  - 2020: GPT-3 with 175 billion parameters;
- 2022: ChatGPT: a popular chatbot built on GPT-3, astonished the general public, sparking numerous discussions and initiatives centered on AI safety;
- 2023: GPT-4 with ca. 1 trillion parameters (OpenAI, 2023), which allegedly already shows some sparks of artificial general intelligence (AGI) (Bubeck et al., 2023).

{ *Source:* Portfolio Optimization: Theory and Applications, 2025, by Daniel P. Palomar }

## Large Language Models

- As we have seen, the phrase *natural language processing* (NLP) refers to broad field of computer science and linguistics focused on how machines process and understand human language.
- I now wish to focus on a subset of NLP, a *Large Language Model* (LLM).
  - This is a large-scale, deep learning-based model (e.g., GPT, BERT) that is trained on massive text corpora.
  - Its purpose is to predict or **generate** language.

# Large Language Models (LLMs)

- Modern LLMs are trained in two main steps:
  - They are pretrained on a large corpus of unlabeled text by using the prediction of the next word in a sentence as a label.
  - They are fine-tuned on a smaller, labeled target dataset to follow instructions or perform classification tasks.

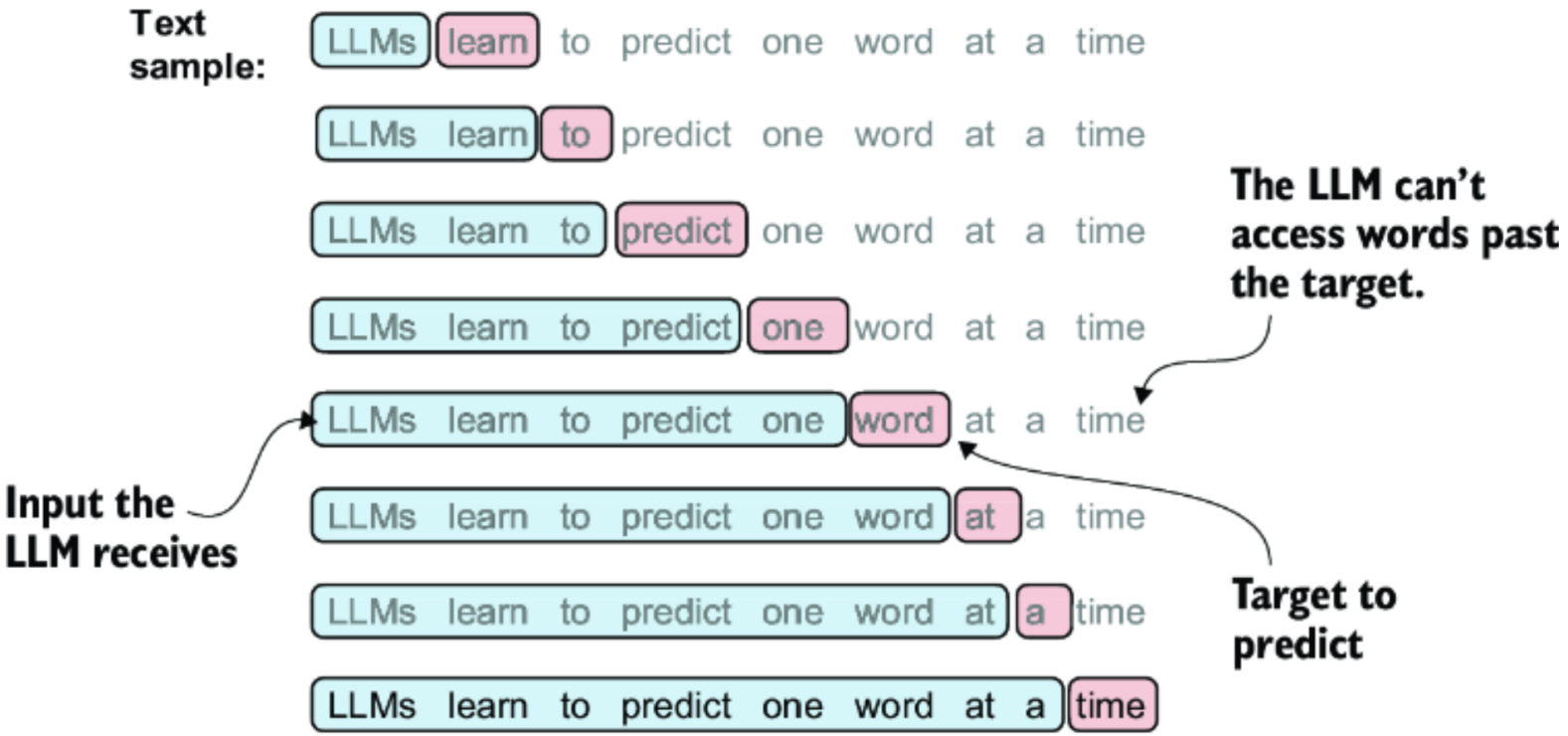



**Figure 2.12 Given a text sample, extract input blocks as subsamples that serve as input to the LLM, and the LLM's prediction task during training is to**

## Word Embedding and Large Language Models

- **Pre-training models**
  - One popular method for training word embeddings is Word2Vec, which uses a neural network to predict the surrounding words of a target word in a given context.
  - Another: GloVe (Global Vectors for Word Representation), which leverages global statistics to create embeddings.
- The embedding size refers to the dimensionality of the model's hidden states.
  - It is a tradeoff between performance and efficiency.
  - The smallest GPT-2 models (117M parameters) use an embedding size of 768 dimensions to provide concrete examples.
  - The largest GPT-3 model (175B parameters) uses an embedding size of 12,288 dimensions.
- The byte pair encoding (BPE) tokenizer used for LLMs like GPT-2 and GPT-3 can efficiently handle unknown words by breaking them down into subword units or individual characters.

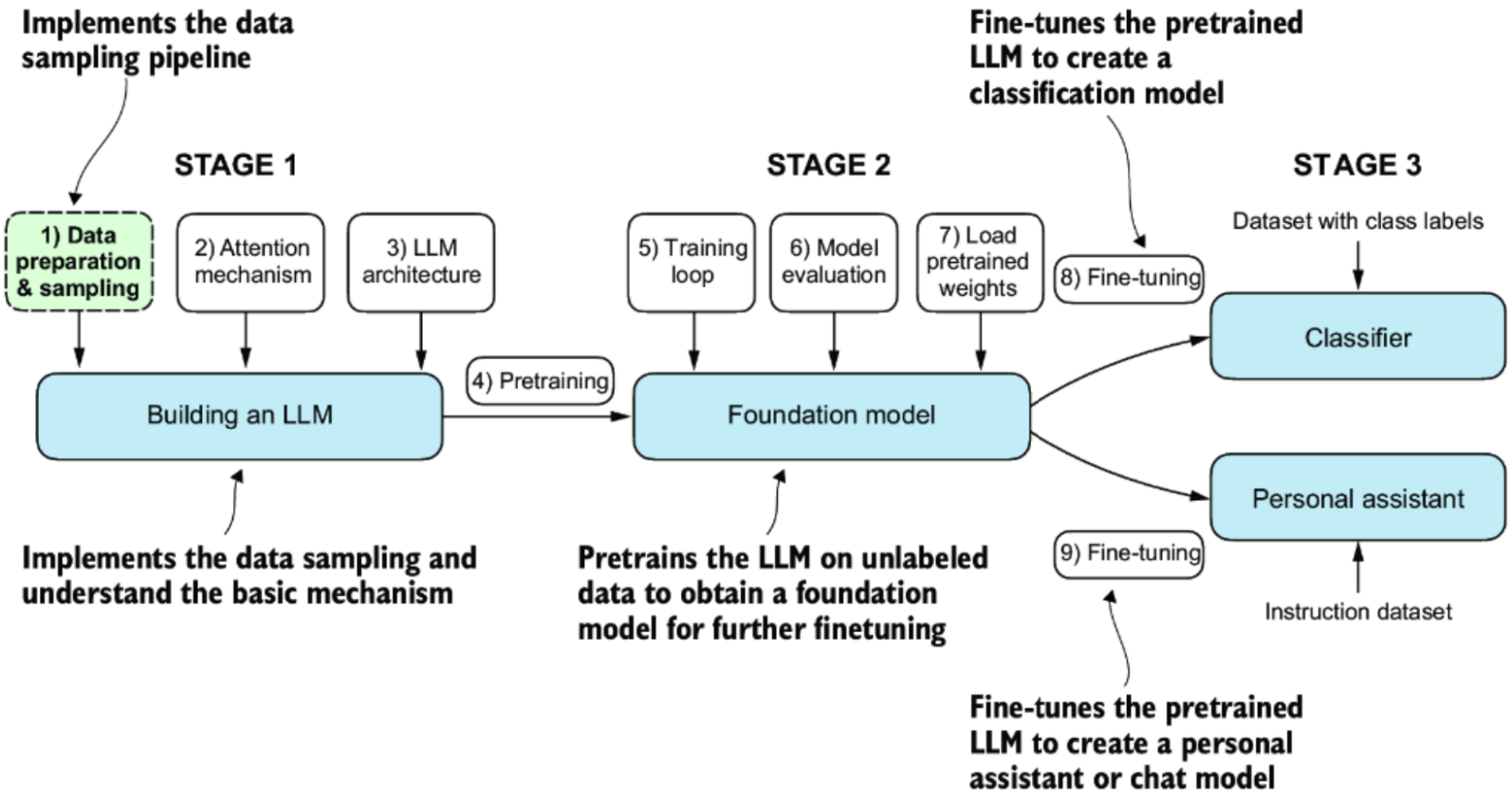
## Features of LLMs

- An LLM is a neural network designed to understand, generate, and respond to human-like text.
- The "large" in "large language model" refers to both the model's size in terms of parameters and the immense dataset on which it's trained.
- LLMs have remarkable capabilities to understand, generate, and interpret human language.
  - They can process and generate text in ways that appear coherent and contextually relevant
  - They **do not** possess human-like consciousness or comprehension.
- LLMs are trained on vast quantities of text data.
  - This allows LLMs to capture deeper contextual information and subtleties of human language compared to previous approaches.

## Disclaimer

- I use ChatGPT as an example of an AI system simply because it is well known.
- There are other great tools available
- In addition, I note that the University of Wisconsin endorses other tools.
  - They prefer Microsoft 365 Copilot Chat and Google Gemini
  - In addition, meeting tools such as Webex AI Assistant and Zoom AI Companion
- Part of the rational is that, unlike public AI services, these tools prevent your data from being used to train AI models while providing secure support for writing, research, and administrative tasks.

- Here is plan for building a LLM.




{ *Credit*: - Build a Large Language Model (From Scratch) }

## Autoencoding

- To understand the transformer architecture, let us first introduce the idea of autoencoding.
- An **autoencoder** is a type of neural network trained to reconstruct its input. It learns a compressed (encoded) representation and then reconstructs the original data from that encoding.
- It consists of two parts:
  - **Encoder**: Compresses the input into a lower-dimensional representation

$$\mathbf{z} = f_{enc}(\mathbf{x})$$

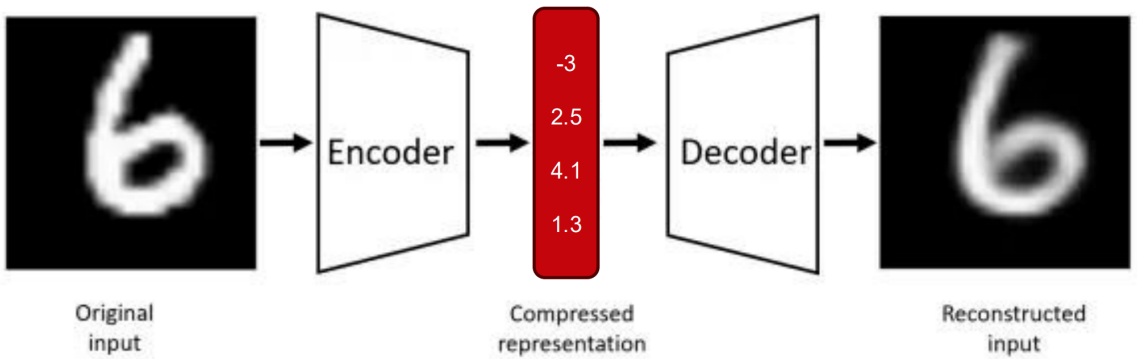
  - **Decoder**: Reconstructs the input from the latent code

$$\hat{\mathbf{x}} = f_{dec}(\mathbf{z})$$

- The network is trained to minimize:

$$||\mathbf{x} - \hat{\mathbf{x}}||^2$$

- Auto-Encoders are neural networks used in unsupervised learning
  - In this way, we can compress image data (recall more traditional methods like principal components analysis)
- Since we condense information (compression!), the predictions generally won't be perfect
  - One can represent the image information via a (limited) set of numbers and thus compare image by similarity of those numbers




If you have time and interest, check out this terrific tutorial on auto-encoders

## Transformer Architecture

- LLMs utilize an architecture called the *transformer*
  - This allows them to pay selective attention to different parts of the input when making predictions
  - It makes them especially adept at handling the nuances and complexities of human language.
- A **transformer** is a deep learning model architecture designed for handling sequences (like language) using a mechanism called **self-attention**.
  - It replaces recurrent models like LSTMs and GRUs with multi-head attention and feedforward layers, enabling fast, scalable training.
- The input embeddings consist of word embeddings and **positional encoders**.

## Positional Encoders

- **Positional encoding** is added to capture word order (since the model lacks recurrence). Transformers process all tokens in parallel (via self-attention), so unlike RNNs or CNNs, there is no inherent sequence or position.
  - The positional encoder is a vector added to the word embedding of each token to indicate its position in the sequence.
  - It is calculated using a deterministic formula involving sine and cosine functions.
  - Sines and cosines are use because the can correspond to a different frequencies and are smooth, continuous, and differentiable patterns.

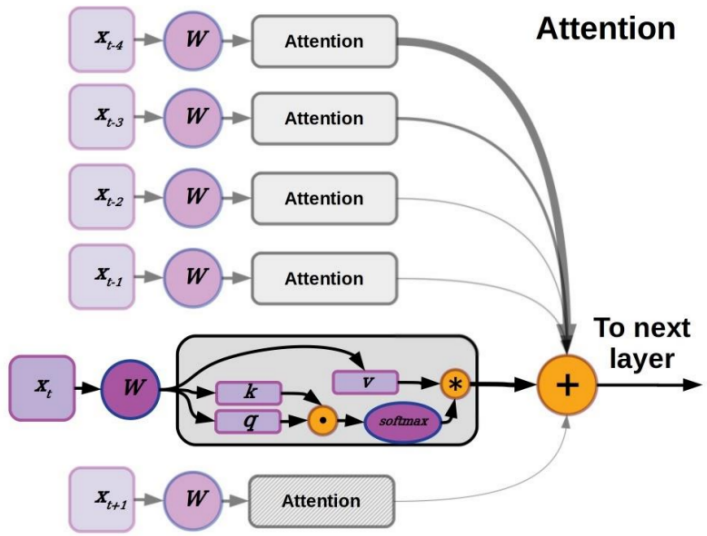
- Just for fun, here are some formulas:

$$\begin{aligned} PE_{(pos,2i)} &= \sin\left(\frac{pos}{10000^{2i/d}}\right) \\ PE_{(pos,2i+1)} &= \cos\left(\frac{pos}{10000^{2i/d}}\right) \end{aligned}$$

- with $pos$ = position in the sequence, $i$ = dimension index, $d$ = total number of dimensions (e.g., 300).

# Attention and Transformers

Transformers are an architecture that pays "attention" to the entire past, and figures out what the important elements are




{ *Credit*: Dani Bauer Lecture Notes }

## Self-attention mechanism

- A key component of transformers and LLMs is the **self-attention mechanism**
  - It allows the model to weigh the importance of different words or tokens in a sequence relative to each other.
  - This mechanism enables the model to capture long-range dependencies and contextual relationships within the input data, enhancing its ability to generate coherent and contextually relevant output.
  - The attention mechanism gives the LLM selective access to the whole input sequence when generating the output one word at a time.
  - In contrast, with a RNN, one only retains a *summary* of the history in a "memory cell". This means one can loose information. Not a problem for short, concise sentences but can be an issue for longer, more complex sentences.

## Attention Mechanism

- Here is an application, translating German to English
- To predict the second token ("you"), the transformer can rely upon previous English words and *all* of the German words.
  - Each word/token receives a so-called "attention weight".
  - Note that the German word "du" has a large black dot, indicating its score is high...

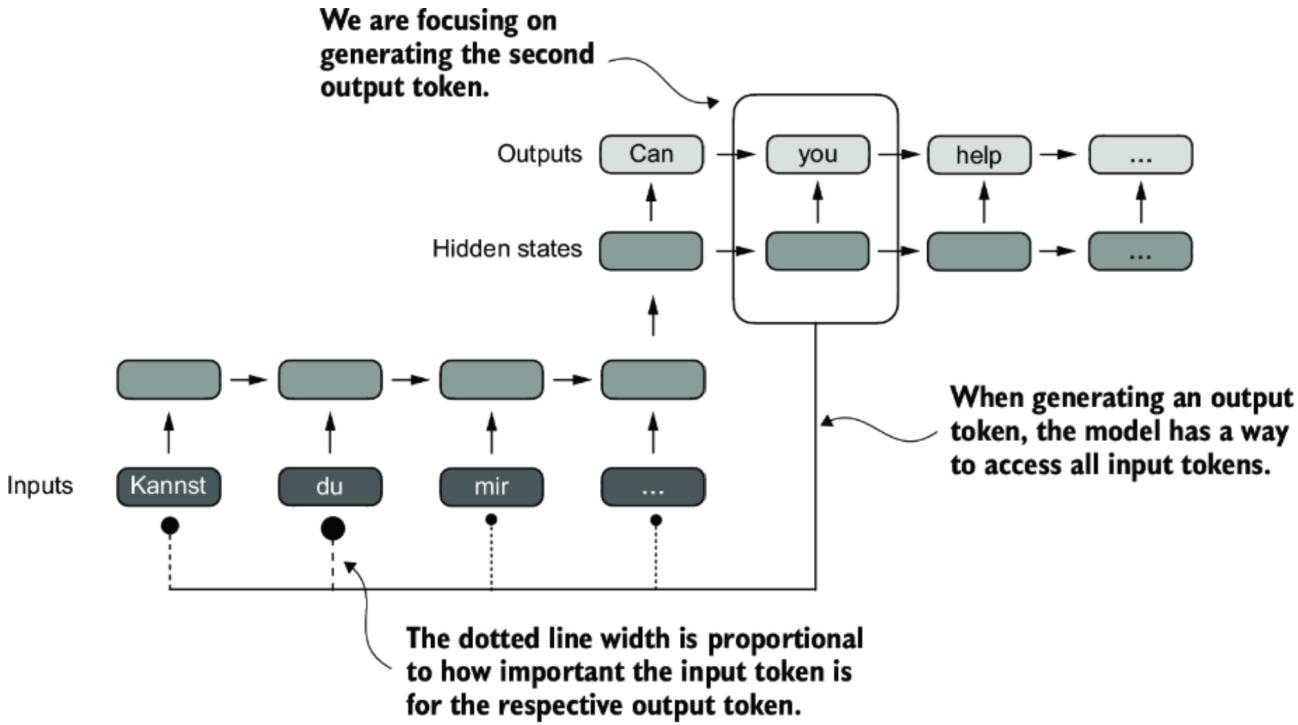



Figure 3.5 Using an attention mechanism, the text-generating decoder part of

## Generative AI

Generative AI is a field within AI focused on creating machines capable of performing tasks that previously required human intelligence.

- Traditional AI: Primarily excels at classification and prediction tasks. Examples include identifying objects in an image (e.g., identifying a "cat").
- Generative AI: Goes beyond classification, excelling at content creation, such as generating new text, images, or music.

Use of deep learning to augment creative activities such as writing, music and art, to generate new things.

Some applications: text generation, deep dreaming, neural style transfer, variational autoencoders and generative adversarial networks.

The following list outlines free tools that are used in specific sub-domains of GenAI:

- **Text**: ChatGPT (Free), Claude, Gemini
- **Images**: Bing Image Creator, Ideogram, Leonardo AI (free tokens)
- **Video**: RunwayML (basic tier), Pika Labs (free credits)
- **PDFs**: ChatPDF, Humata
- **Product mockups**: Kittl, Canva AI

{ *Source:* https://www.analyticsvidhya.com/blog/2025/05/getting-into-gen-ai/

See also https://www.linkedin.com/pulse/what-generative-ai-llm-luis-escalante. }

## Resources For Future Studies

- Sebastian Raschka Build a Large Language Model (From Scratch)
  - Raschka Teaching Site
- "Speech and Language Processing" by Dan Jurafsky and James H. Martin
  - *Course:* Stanford CS224n - Natural Language Processing with Deep Learning - YouTube Lectures