Hands-on with Generative AI

INTERVIEW KICKSTART

Instructor: Michael Bazzoli

A little about me, Michael Bazzoli

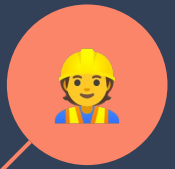
Staff MLE - DataRobot adding GenAI/LLM features
Prev: MLE @ Amazon, Wyze, Microsoft

Computer Engineering –
University of Illinois @ Urbana-Champaign

Based in Los Angeles, CA

Welcome to today's class, before we begin, pop into the chat:

Your Name



Role

Location

Company

Optimize Your Experience

- ✅ Interact with your instructors via Sunday live class.
- ✅ Don’t be shy to speak up and get clarifications !

- ✅ Solve your assignments, MCQs and other assessments and get feedback (Thursday review session)
- ✅ Use your resources! It’s your experience – what you put in is what you’ll get out.

What happened before?

- In past sections you gained exposure to the Python programming language
- Here we will use Python to work hands-on with Generative AI models
- Your past exposure to Python should be sufficient to follow along with the high-level concepts in the examples that we present here
- There will be some details that likely will not be familiar to you...
- ...don't worry, this is just a first look at how to use Python for Generative AI
- ...you will have plenty of time to practice in later sections


QUIZ
TIME!

Recap Quiz

What is a Python module?

A A data type with member variables and methods associated with it.

B An immutable data structure containing a list of values.

C A file containing Python code that can be imported inside a program.

D A computer program that converts Python code into machine code.

Recap Quiz

What is a Python module?

A A data type with member variables and methods associated with it.

B An immutable data structure containing a list of values.

C A file containing Python code that can be imported inside a program.

D A computer program that converts Python code into machine code.

Learning Objectives for Today

- Get a **high-level** overview of generative AI capabilities available today:
  - How text-to-text models work
  - Text-to-text models that are widely used today
  - How to invoke text-to-text models in Python
  - How text-to-image models work
  - Text-to-image models that are widely used today
  - How to invoke text-to-image models in Python
- We try to give a broad view with limited details (esp. on how models work)
- We will dive deeper in later modules

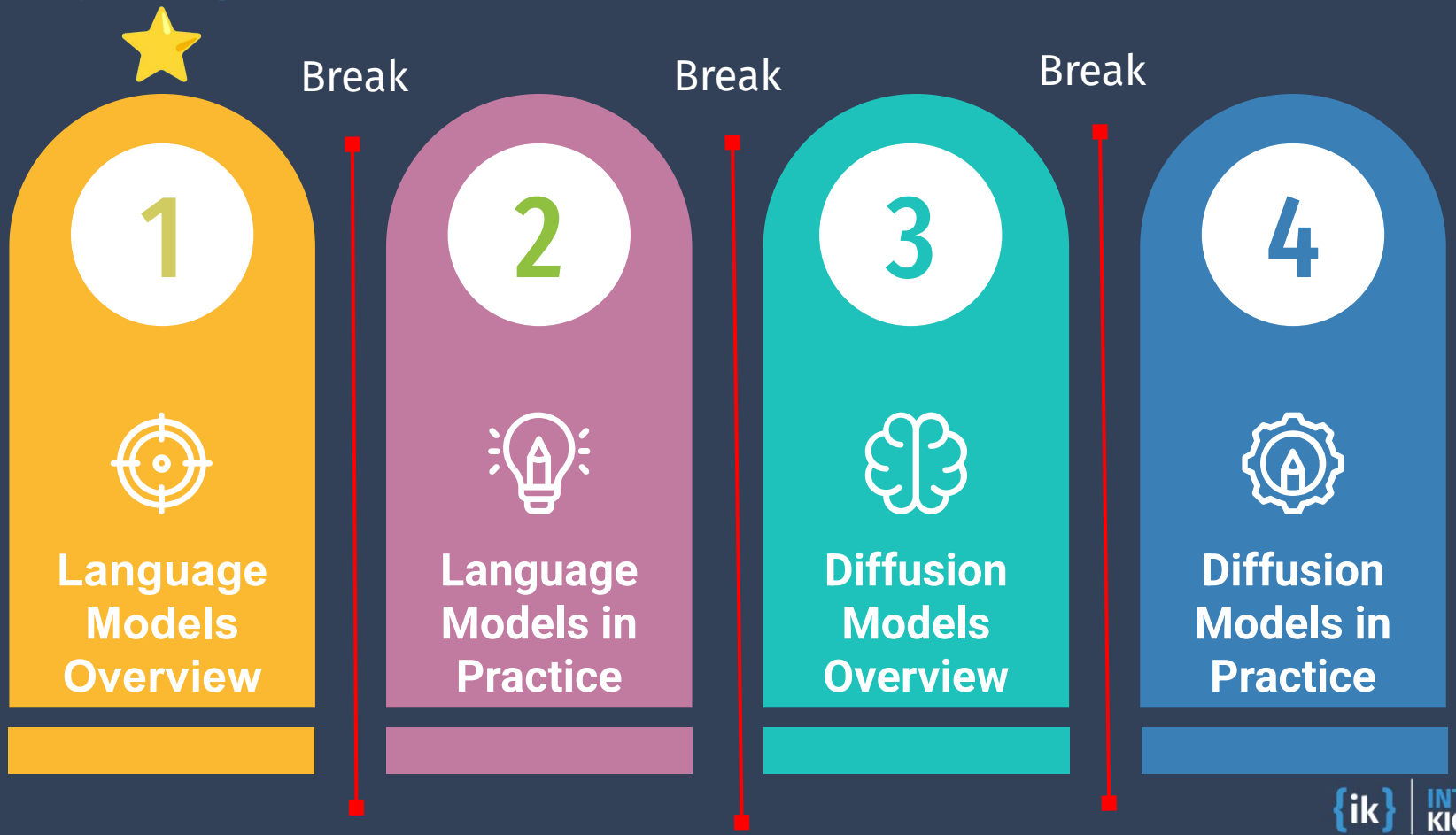
Today's Agenda

	1st Hour (9-10 PT)	2nd Hour (10-11 PT)	3rd Hour (11-12 PT)	4th Hour (12-1 PT)
h:00 - h:15	Introduction	Demonstration of Language Model API and Open Source Model	Overview of Latent Diffusion Models	Demonstration of Text-to-Image API and Open Source Model
h:15 - h:55	Overview of Language Models			
h:55 - h:00	Break	Break	Break	Summary

How is Today's Content Relevant to my Role?

- **PMs:** Understand what types of Generative AI product features could be build with currently available tools.
- **TPMs:** Understand the technical feasibility and requirements of implementing certain generative AI features.
- **SDEs:** Become familiar with how to implement Generative AI capabilities in applications.
- **Engineering Managers:** Become familiar with options available for integrating Generative AI capabilities into the applications that you own.
- **DevOps Engineers:** Get a first look at software and infrastructure requirements for running or accessing Generative AI models.

Today's Agenda

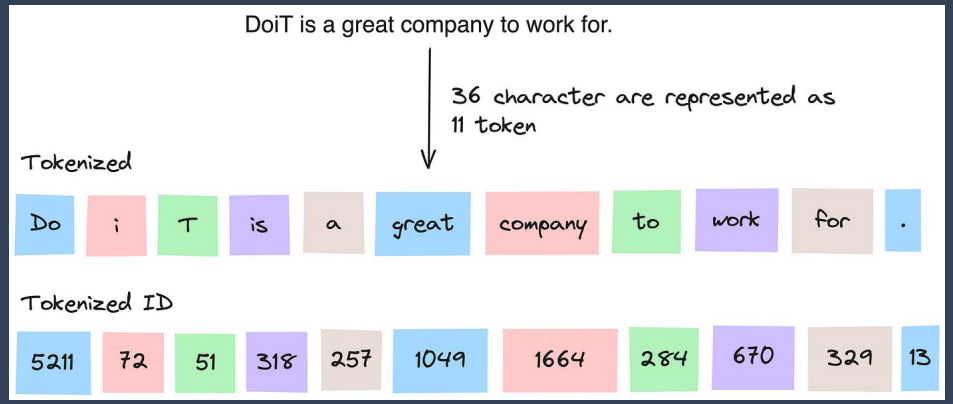


TOPIC #1
Language Models Overview

Overview

- In this section you will:
  - Learn what a *language model* is
  - Understand how language models are used to generate text
  - Understand why building accurate language models is difficult
- We will mention the Transformer architecture, but not cover details yet

Modeling Text



- A *language model* is at the heart of applications like ChatGPT
- A language model is a statistical model that can be used to generate text
- Generating text can be cast as a problem of generating sequences of *tokens*
- Tokens are represented by unique IDs, each corresponding to a word or part of a word in the model's vocabulary

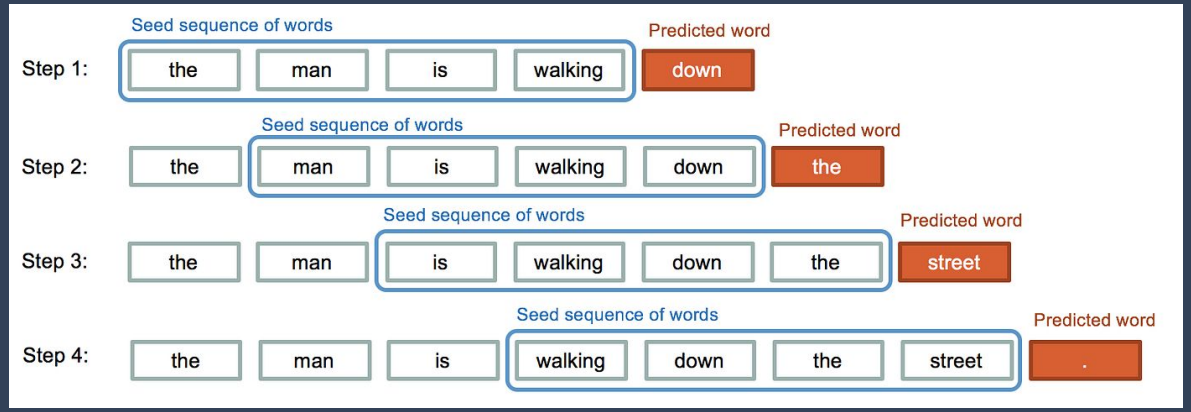
Language Models

- A language model is given by conditional probabilities over tokens:

$$P(w_{n+1} | w_n, \ldots, w_1)$$

- We call the sequence $w_1, \ldots, w_n$ the *context*
- For example, you give the model the context: “This morning I went to the”...
- ...and get probabilities that each token in your vocabulary is the next token:
  - *P* (“office”|previous tokens) = 0.031
  - *P* (“store”|previous tokens) = 0.028
  - *P* (“local”|previous tokens) = 0.027
  - *P* (“gym”|previous tokens) = 0.023
  - ...

Predicting the Next Token in a Sequence



- If we can predict just the next token, we can generate a sequence
- That is, given a context select the next token…
- …then add that token to the context and repeat
- How should we select the next token from the probability model?

Generating Text

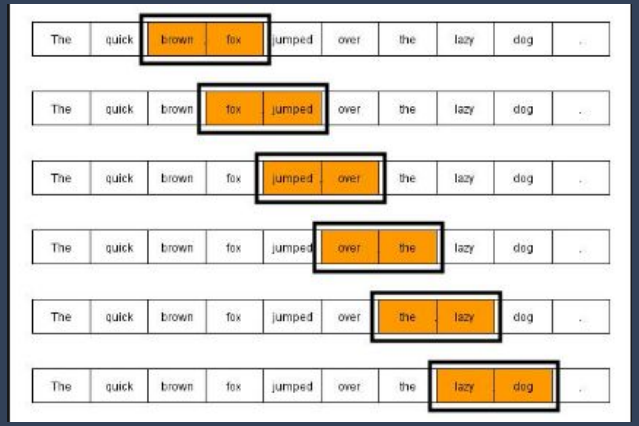
- As an example, this text is generated given this context:
  "This morning I went to the office as I usually do on weekdays."

- The concept of text completion is very versatile:

"Question: What is the largest city in the world? Answer: Tokyo."

"Human: How are you? Chatbot: I am well, thanks."

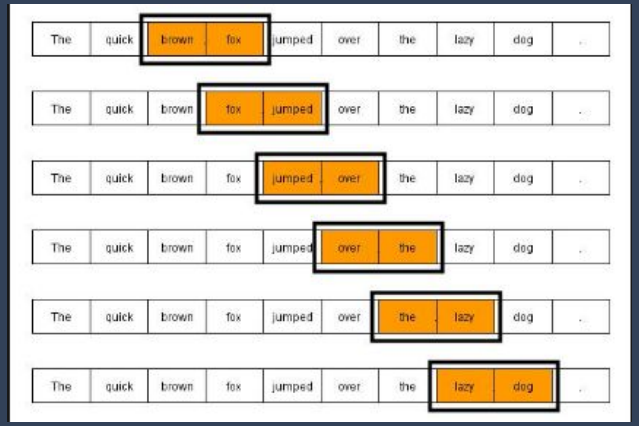
Simple Language Models - *n*-grams



$$P(w_i|w_{i-1}) = \frac{\text{Count}(w_{i-1}, w_i)}{\text{Count}(w_{i-1})}$$

- Language models are built by training on a large corpus of text
- Models are trained on the task of predicting the next word given context
- Consider the simple model that only uses the previous word as context
- This is called the *bigram* model

Simple Language Models - *n*-grams (cont.)



$$P(w_i|w_{i-1}) = \frac{\text{Count}(w_{i-1}, w_i)}{\text{Count}(w_{i-1})}$$

- Training a bigram model is simple...
- ...record the frequency of occurrence of each word for each previous word
- Can generalize this idea to the *n-gram* model
- In general, record word frequencies for each previous *n*-1 words

Challenges with modeling long contexts

Suppose our vocabulary consists of *V* tokens:

- When we build an *n*-gram model we need to store:
  - Probabilities for each next token in V, for all observed n–1 contexts

- Theoretically there are V^{n-1} possible contexts, though the number stored depends on the training data and smoothing techniques. Usually there are significantly less. An for each context V probabilities for next token so V^n

- **What happens as we increase *n*?**

Long contexts are necessary

- Consider the example, where text is generated with limited context:

"My dog is named Joey. Yesterday Joey and I went for a long walk by the river. The spring weather was beautiful, and many people were out enjoying the day. Joey was happy too. I know this because he told me so."

- The fact that Joey is a dog is important, but that information is outside the context used in this example.

Effectively modeling long contexts

- Various models have been used to capture-range dependencies
- Effective models are generally based on deep neural network architecture
- For example, recurrent neural networks (RNNs, LSTMs, GRUs) were a commonly used architecture for this task in the past
- Since 2017, the *Transformer* has been the dominant model architecture for language models
- Transformers remove some of the complexity of RNNs
- This results in larger, more performant models that can be trained in less time than previous RNN architectures
- Transformers will be covered in detail in later modules

Summary

01 Language models capture statistical relationships in sequences of tokens

02 Text is generated from a LM by conditioning on prior context

03 Models predict probabilities of the next single token given a context

04 Developing models that capture long-range dependencies is challenging

05 The Transformer effectively models dependencies within long contexts


QUIZ
TIME!

Topic #1 Quiz

What is the primary purpose of tokenization in language models?

A To convert text into numerical representations.

B To train the model on large dataset.

C To generate new text from the model.

D To optimize the model's performance.

Topic #1 Quiz - Solution

What is the primary purpose of tokenization in language models?

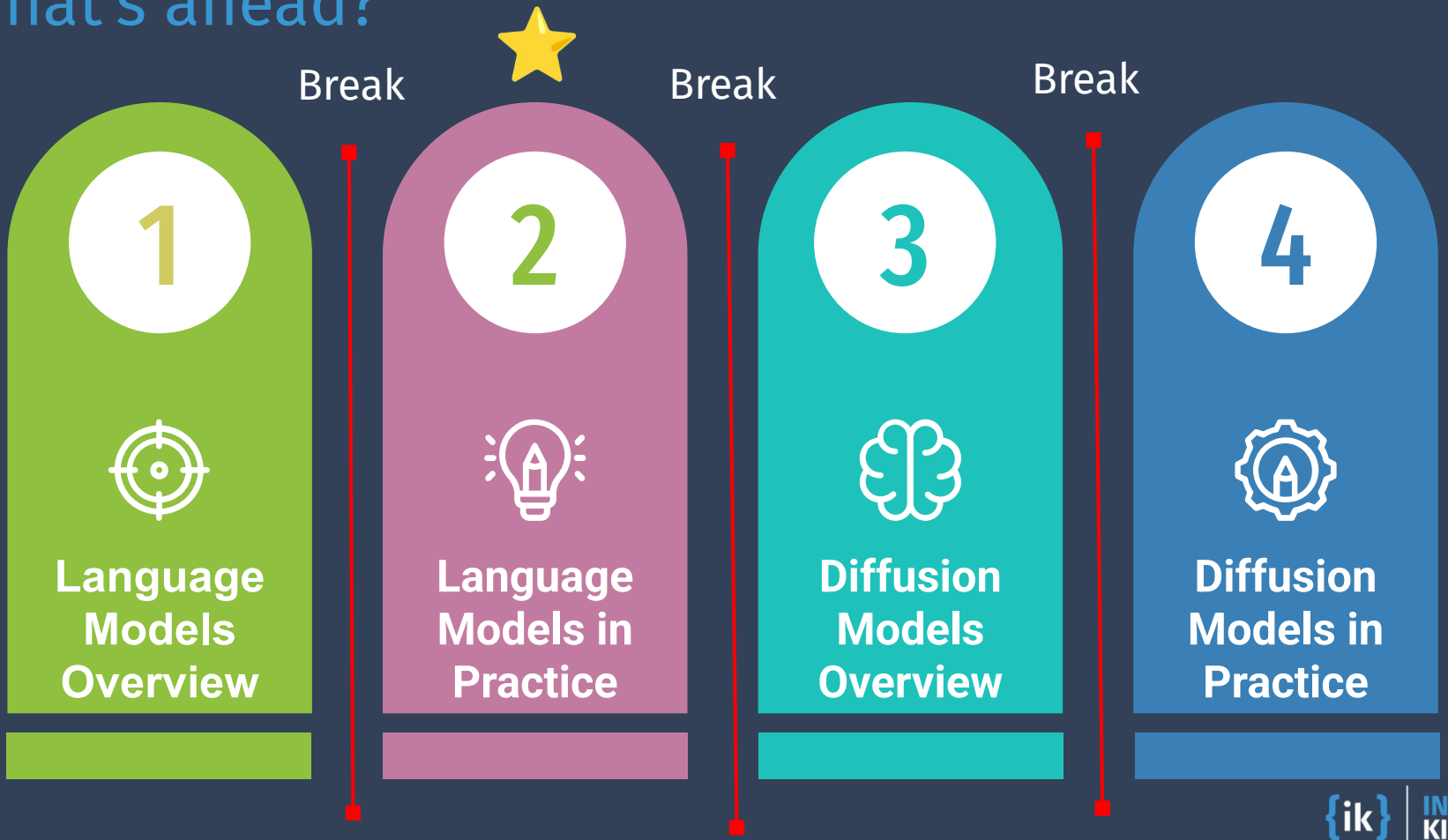
A To convert text into numerical representations.

B To train the model on large dataset.

C To generate new text from the model.

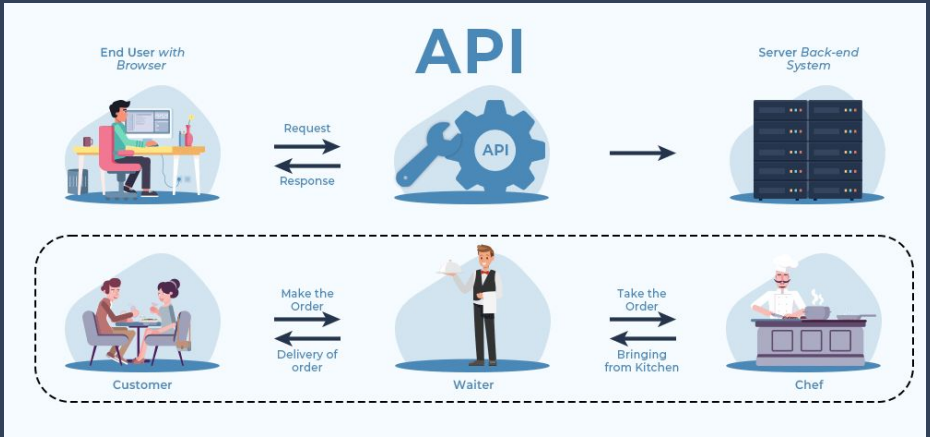
D To optimize the model's performance.

What's ahead?



TOPIC #2
Language Models in Practice

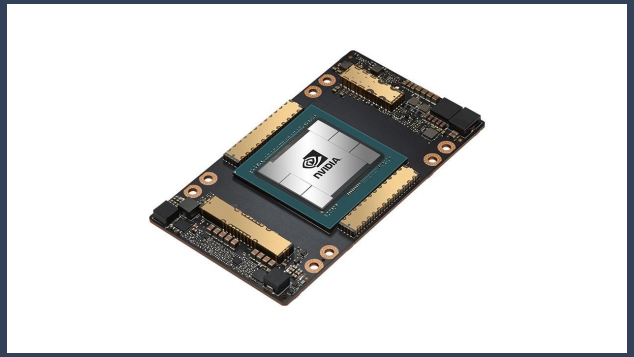
Background: What is an API?



Source: geeksforgeeks.org

- A *web API* (application programming interface) enables applications to access functionality that is hosted on a remote system
- Applications make calls that are sent over the internet to a remote system…
- …the remote system produces a result and sends back to the application

Background: What is a GPU?



- A GPU (graphics processing unit) is a processor initially designed for parallelizing certain graphics-related computations
- The same types of computations are performed by machine learning models
- GPUs can be used to accelerate these computations, which is key for the large models used in Generative AI

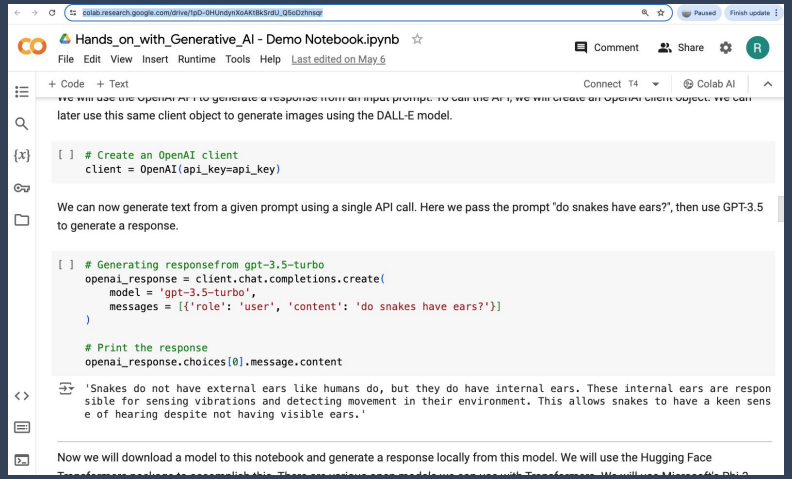
Survey of Large Language Models

- ChatGPT drew enormous public attention to the capabilities of Large Language Models (LLMs)
- There are now many capable LLMs available, and the landscape is rapidly evolving
- We will cover some examples of both closed and open-source models
- Closed models are generally only accessible through APIs, and weights and details of model structure are not publicly known
- The weights and source code for open-source models are freely available and can be modified and customized by developers

Survey of Closed Models

- As of April 2024, some of the most popular and performant models are:
  - OpenAI's GPT-4 model
  - Anthropic's Claude model
  - Google's Gemini model
- This keeps changing as new models are released/updated. Today GPT 4o, o3, Deepseek reasoning models, Gemini advanced, and variants of Claude and Llama 3 do very well.
- These models can be integrated into applications by accessing via APIs
- Cloud services such as Amazon Bedrock or Azure OpenAI Service can be used to access multiple closed models through a single API interface

OpenAI GPT-x model Demonstration

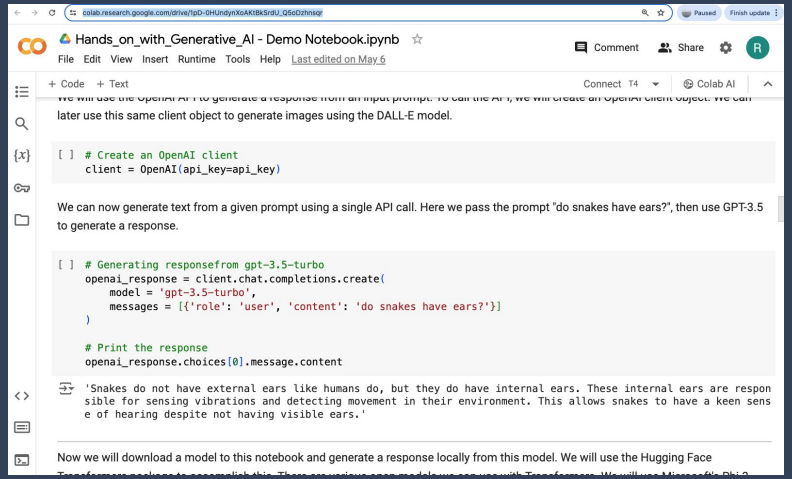


- [Demo Notebook]
- Here we will demonstrate how to access a GPT model via the OpenAI API.

Survey of Open-Source Models

- As of April 2024, some of the most popular and performant models are:
  - Meta's LLaMA models (LLaMA 3 released in April 2024)
  - Mistral AI's Mistral 7B, Mixtral 8x7B, and Mixtral 8x22B models
  - Microsoft's Phi-3 "small" language models
  - Deepseek V3 (Dec 2024)
- Weights for the open source models can be accessed from the Hugging Face platform
- Models can be loaded and integrated into Python applications using the Hugging Face "transformers" Python library

Open Source Model Demonstration



- Demo Notebook
- Here we will demonstrate how a model can be loaded and invoked using the transformers library.

Summary

01 Closed models can be used within applications via their APIs

02 Source code and model weights are available for several open-source models

03 OpenAI, Anthropic, Google, and others all provide access to LLMs via APIs

04 Popular performant open models include LLaMA, Deepseek, and others

05 Hugging Face provides a platform and tools for easily working with open models


QUIZ
TIME!

Topic #2 Quiz

Which company developed the GPT-3 language model?

A Google.

B OpenAI.

C Anthropic.

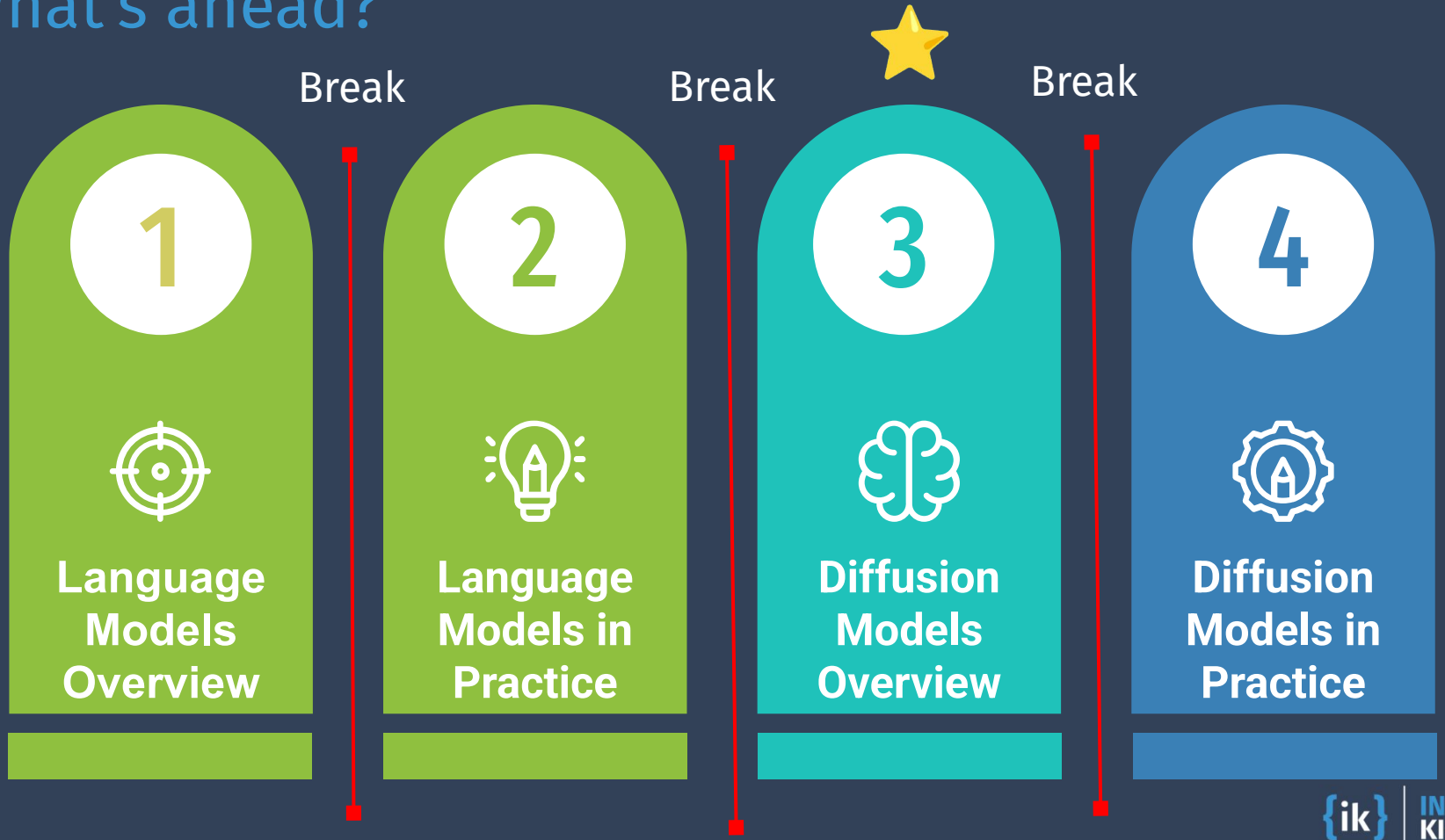
D DeepMind.

Topic #2 Quiz - Solution

Which company developed the GPT-3 language model?

- **A** Google.
- **B** OpenAI.
- **C** Anthropic.
- **D** DeepMind.

What's ahead?

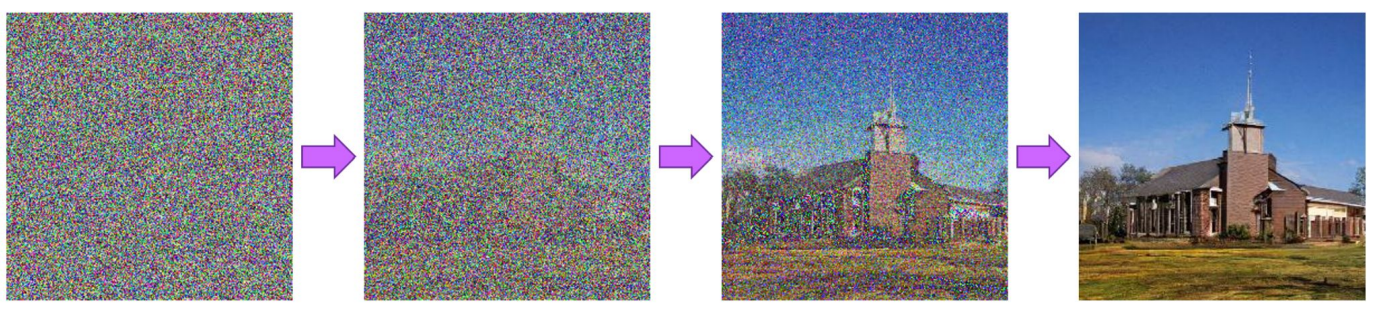


TOPIC #3
Diffusion Models Overview

Overview

- In this section you will:
  - Learn what a *diffusion model* is
  - Understand how diffusion models are used to generate images
  - Understand how generation can be conditioned on text prompts
  - Understand how *latent diffusion models* make generation more efficient
- This is a high-level presentation, with details to come in later modules

Generating Images with Diffusion Models

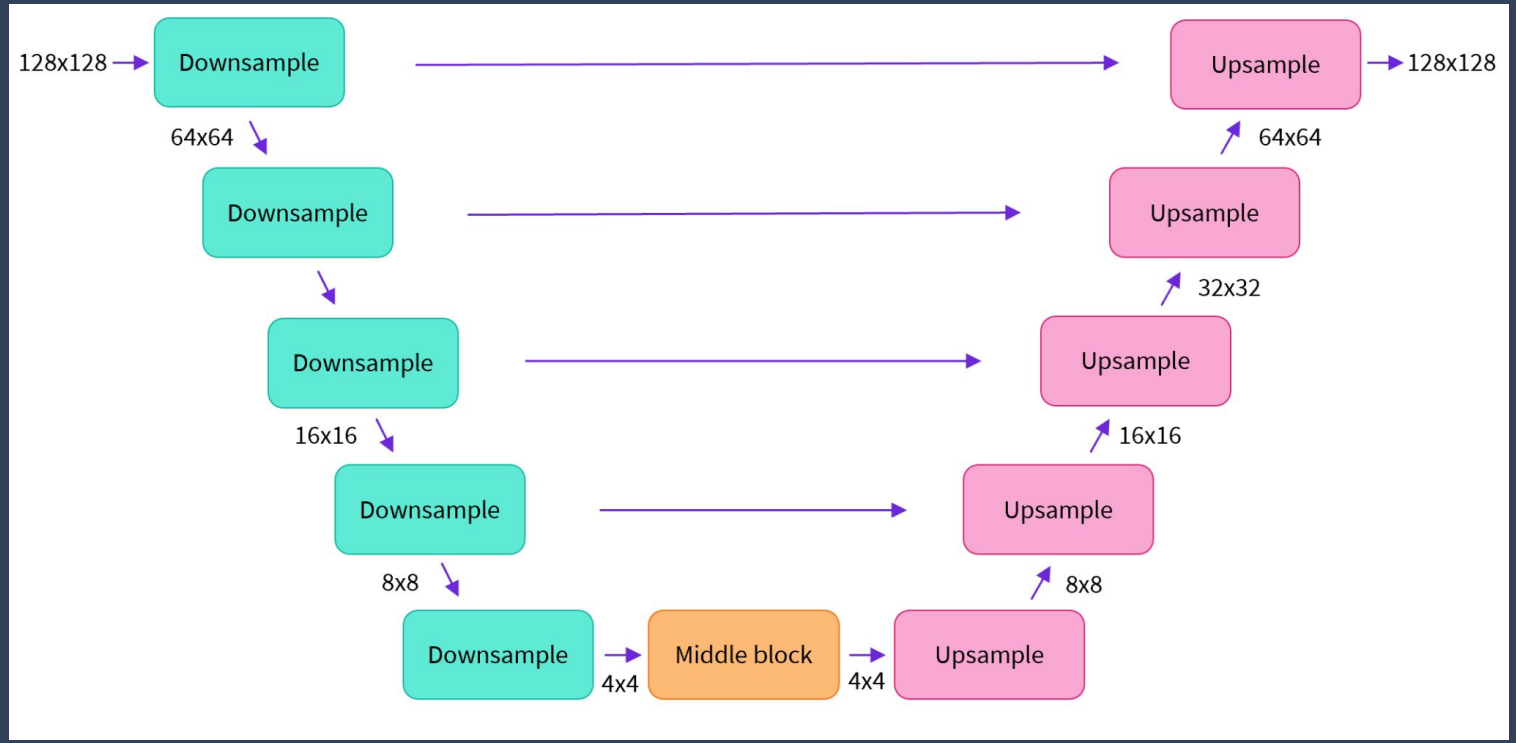


- Diffusion models generate sample images from some learned distribution of images
- Specifically, diffusion models learn how to generate a slightly less noisy image from a given noisy image
- Images are sampled by starting with random noise, then iteratively denoised until we have a coherent image

Unconditional Generation

- We can train a model that generates random images from some distribution of images (e.g., cats, churches, celebrities)
- To achieve this, a diffusion model is trained on sample images from the desired distribution
- To train the model, we add noise to training images and learn to approximately recover the input images
- This allows us to use the model to feed in random noise, and recover a random image from the input distribution
- The specific model architecture most often used is the *U-Net*

The U-Net Architecture



Conditional Generation

- Alternatively, we can train a model on a broader collection of images, then restrict the image content when generating
- The model can be augmented to allow for additional external inputs for guiding image generation (e.g., text, other images)
- A text-to-image model of this form is composed of a text encoder coupled with a U-Net

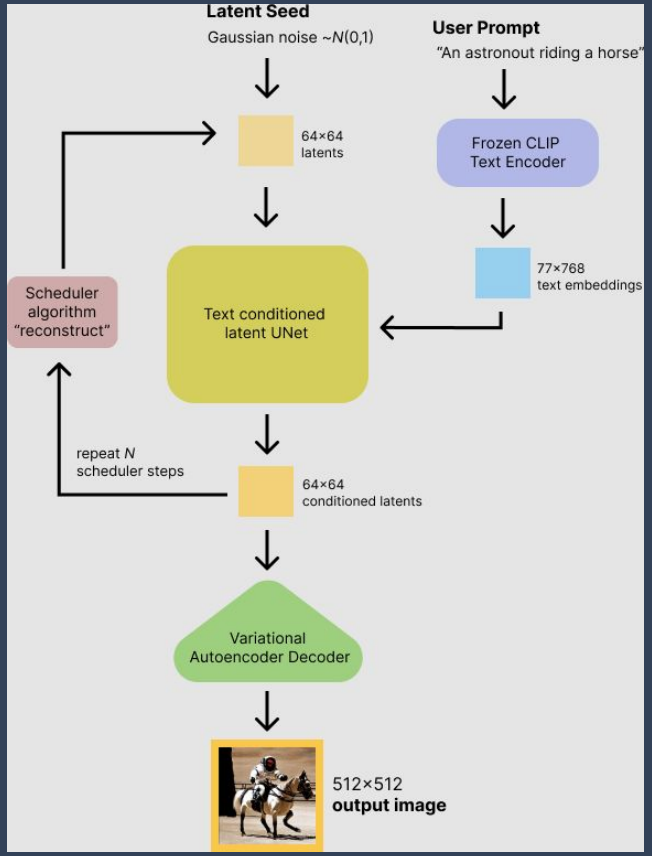
Challenges with Using Diffusion Models

- The input and output of the U-Net are images of the size and resolution of the images that we want to generate
- Generating large, full-color images can be slow, and training a model to has high computational and memory requirements
- As a result, it is more efficient to work with a compressed representation of the images
- When generating an image, the U-Net generates a compressed representation of the image (in the “latent” image space), then this latent representation expanded into a full image

Latent Diffusion Models

The final model contains the following components:

- A **text encoder** for creating text embeddings
- A **text-conditioned U-Net** for generating images in the latent space
- A **variational autoencoder** for converting the latent image into a full image
- A **scheduler** for controlling the iterative generation process



Summary

01 Diffusion models generate images by denoising random noise

02 Denoising is performed by a scheduler that invokes the denoising model

03 Denoising can be conditioned on a text prompt

04 The diffusion process can be slow and inefficient when applied directly to images

05 Diffusion can be performed in a latent space, then an image is generated from VAE


QUIZ
TIME!

Topic #3 Quiz

Which of the following is a key challenge in diffusion models?

A Overfitting.

B Underfitting.

C Slow sampling process.

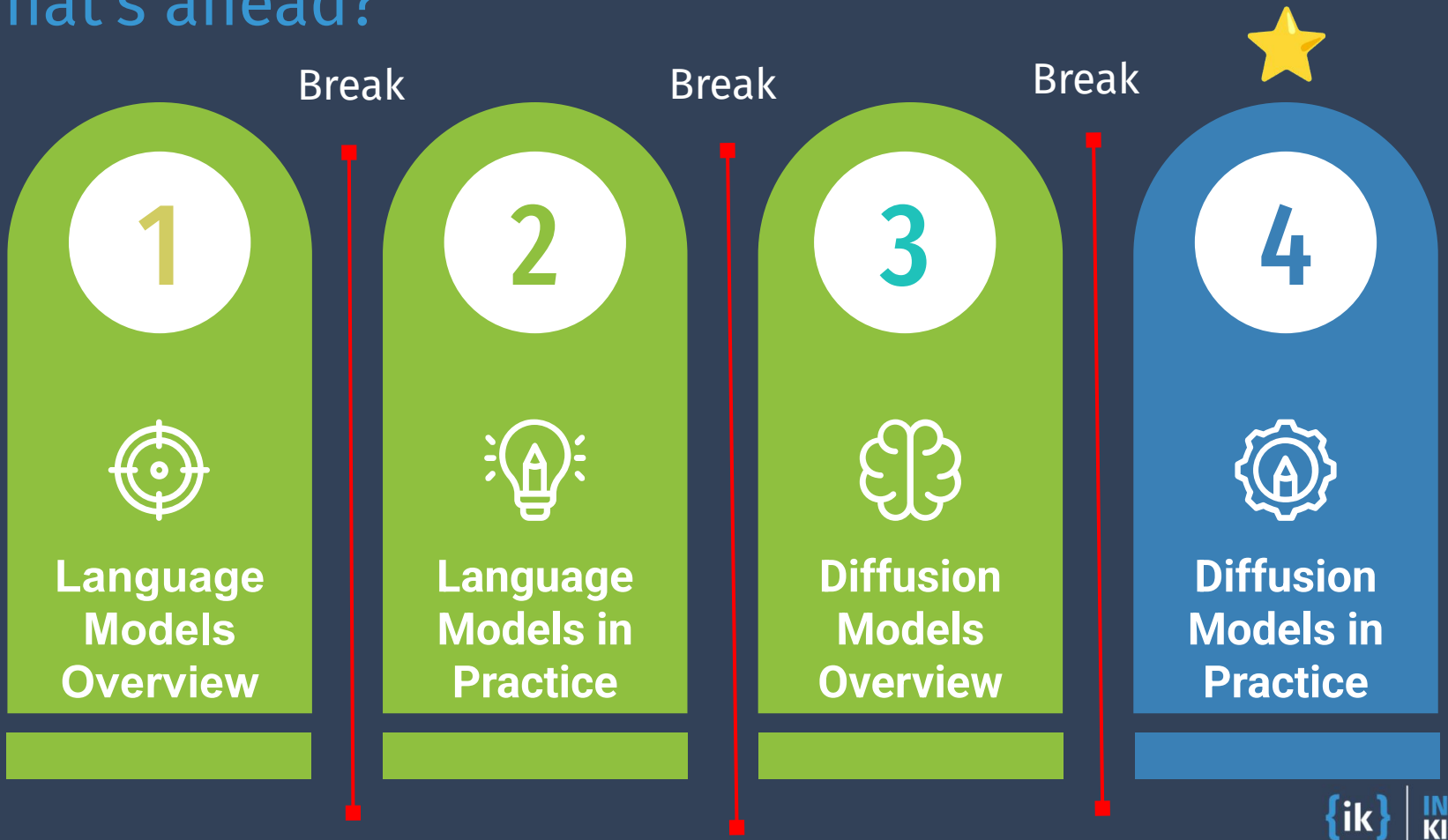
D Difficulty in training.

Topic #3 Quiz - Solution

Which of the following is a key challenge in diffusion models?

- **A** Overfitting.
- **B** Underfitting.
- **C** Slow sampling process.
- **D** Difficulty in training.

What's ahead?

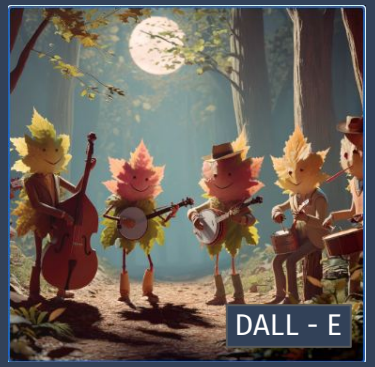


TOPIC #4
Diffusion Models in Practice

Survey of Text-to-Image Models

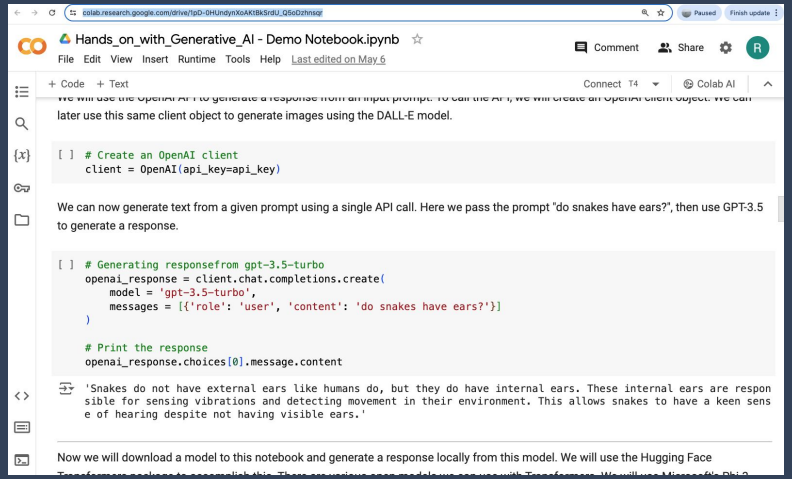
- As with language models, there are multiple capable text-to-image models
- We will cover some examples of both closed and open-source models
- Closed models are generally only accessible through APIs, and weights and details of model structure are not publicly known
- The weights and source code for open-source models are freely available and can be modified and customized by developers

Survey of Closed Models



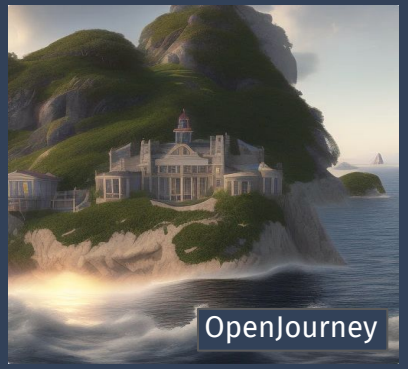
- As of April 2024, some of the most popular and performant models are:
  - OpenAI's DALL-E model
  - Midjourney
  - Google's Imagen model
- These models can be integrated into applications by accessing via APIs

DALL-E Demonstration



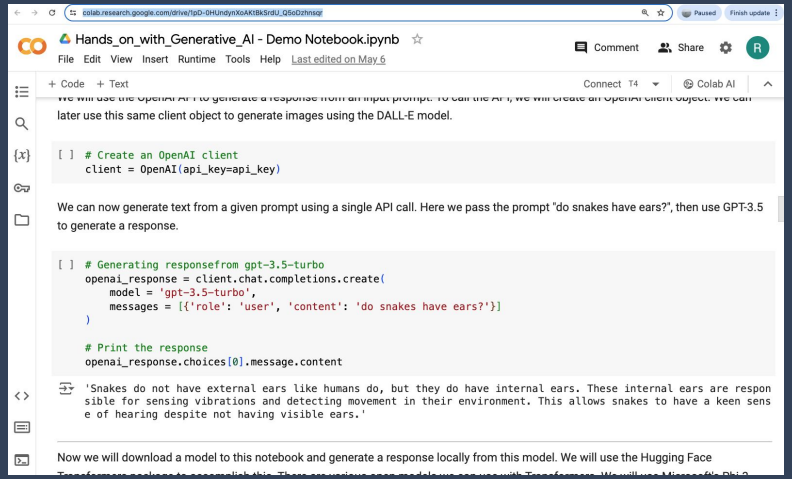
- Demo Notebook
- Here we will demonstrate how to access DALL-E via the OpenAI API.

Survey of Open-Source Models



- As of April 2024, some of the most popular and performant models are:
  - Stability AI's Stable Diffusion model
  - PromptHero's OpenJourney model
- Weights for these models can be accessed from the Hugging Face platform
- Models can be loaded and integrated into Python applications using the Hugging Face "diffusers" Python library

Open Source Model Demonstration



- Demo Notebook
- Here we will demonstrate how Stable Diffusion 3 can be loaded and invoked using the diffusers library.

Summary

01 Closed models can be used within applications via their APIs

02 Source code and model weights are available for several open-source models

03 OpenAI and Google's Imagen provide access to text-to-image models via APIs

04 Stable Diffusion is a popular performant open model

05 Hugging Face provides a platform and tools for easily working with open models


QUIZ
TIME!

Topic #4 Quiz

Which of the following is an open-source text-to-image model?

A DALL-E 2.

B Stable Diffusion.

C DALL-E.

D Imagen.

Topic #4 Quiz - Solution

Which of the following is an open-source text-to-image model?

- **A** DALL-E 2.
- **B** Stable Diffusion.
- **C** DALL-E.
- **D** Imagen.

Class Summary

Topic 1	Language Models are probabilistic models of text sequences	Modeling long-range dependencies is challenging	The Transformer model is SOA
Topic 2	There are capable closed and open models	Closed models include GPT-4, Claude, and Gemini	Open models include LLaMA, Mistral, and Falcon
Topic 3	Diffusion Models are used to sample images	Model output can be conditioned on text prompts	Latent Diffusion Models use work with compressed images
Topic 4	There are capable closed and open models	Closed models include DALL-E, Midjourney, and Imagen	Open models include Stable Diffusion and OpenJourney