IBM

# Generative AI on Amazon SageMaker - Deep Dive

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AWS

# Agenda

Evolution of LLMs

I am lost

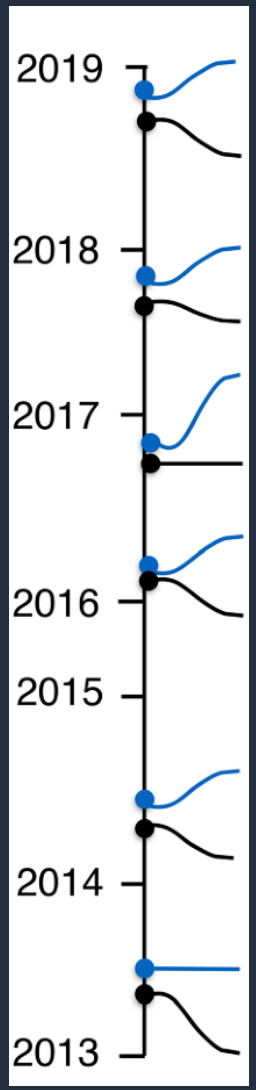
Best practices for Model Tuning

Amazon Distributed Training – for Model Tuners and Providers



# Evolution of LLMs

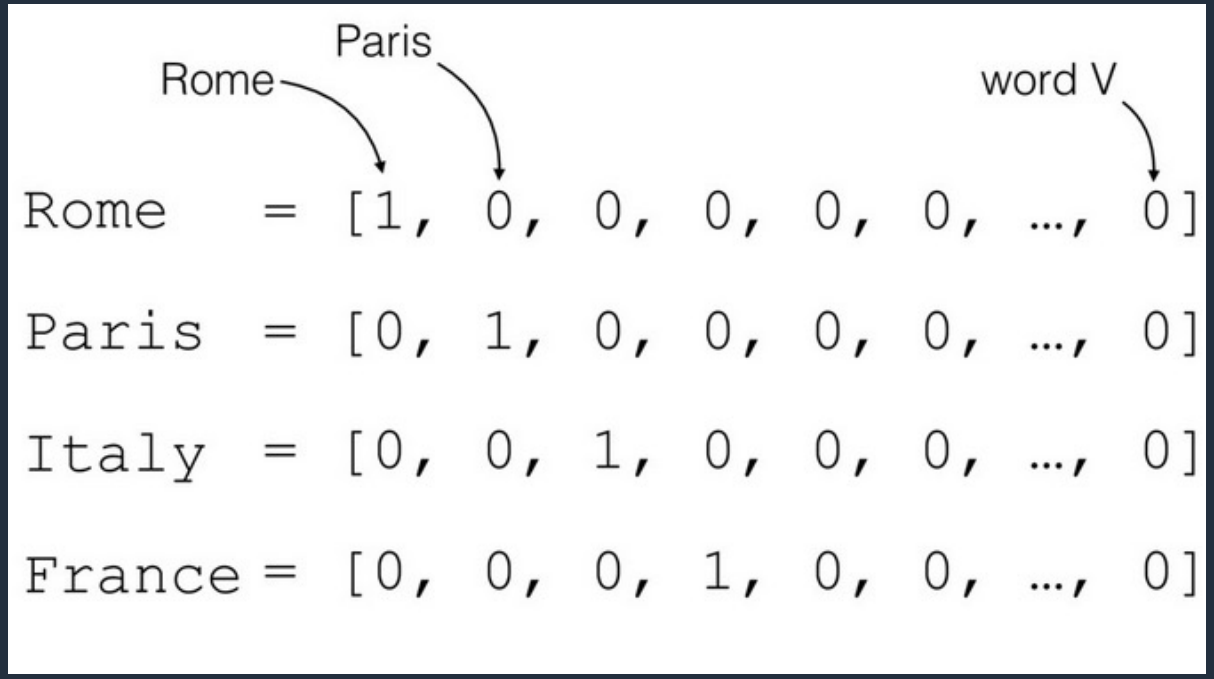
# The timeline




- RoBERTa
- GPT - 2
- BERT
- Generative Pre-trained Transformer (GPT)
- Attention is All You Need
- Seq2Seq - RNN & CNN
- Glove
- Word2Vec (CBOW, Skip-gram)

# Dive Deep

# It started not long ago

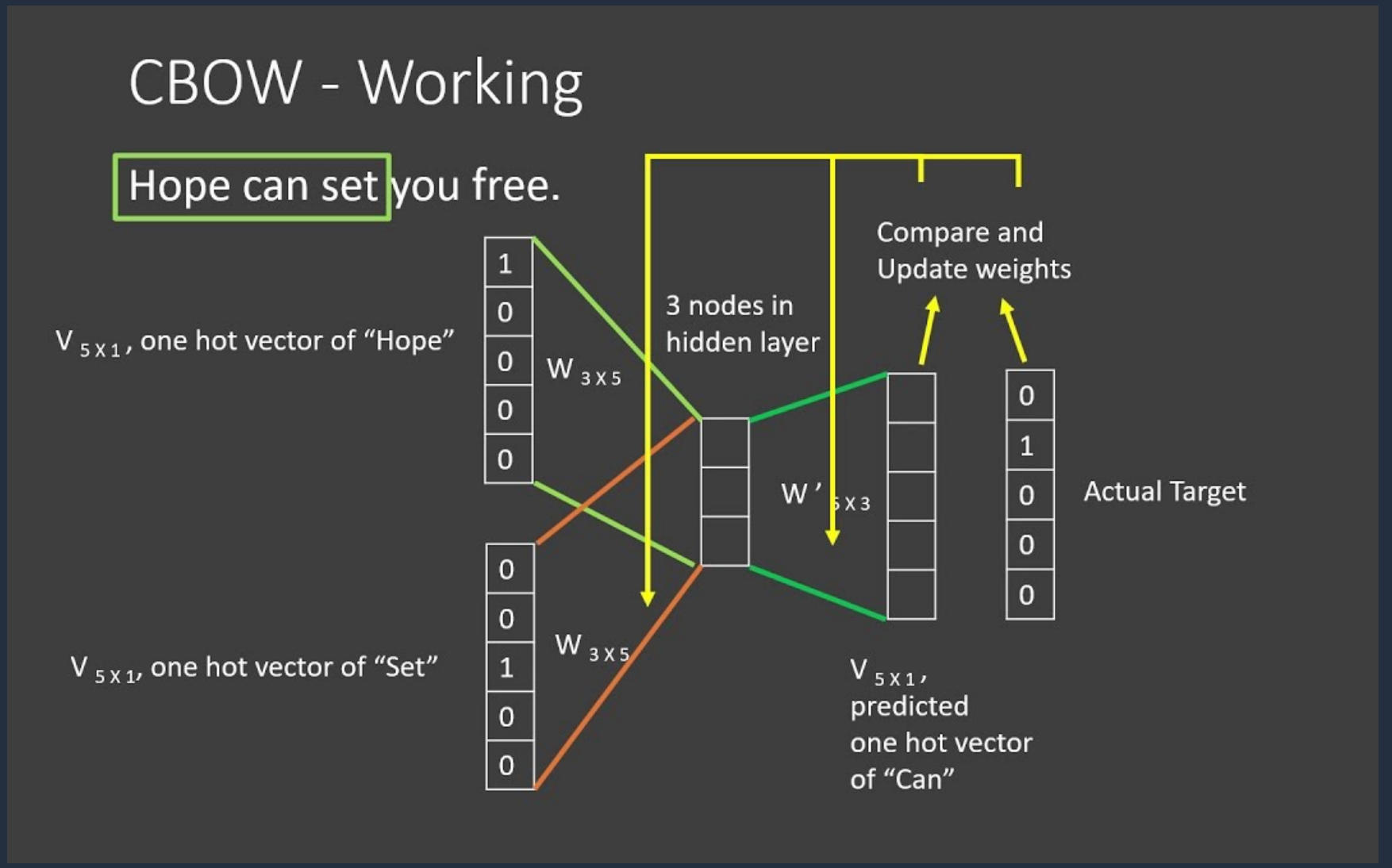



**Pros**: Its numbers, computer can process

**Cons: It doesn't capture the meaning**

# Dive Deep

# CBOW - Working



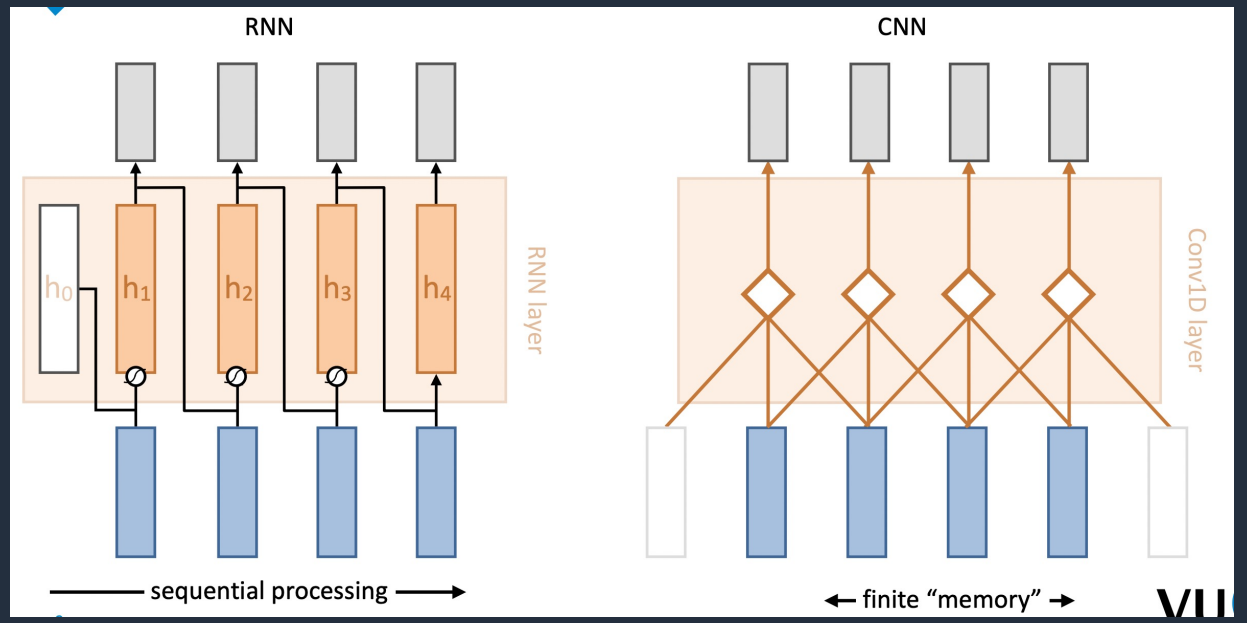

https://www.youtube.com/watch?v=UqRCEmrv1gQ

**Pros**: It captures meaning and context

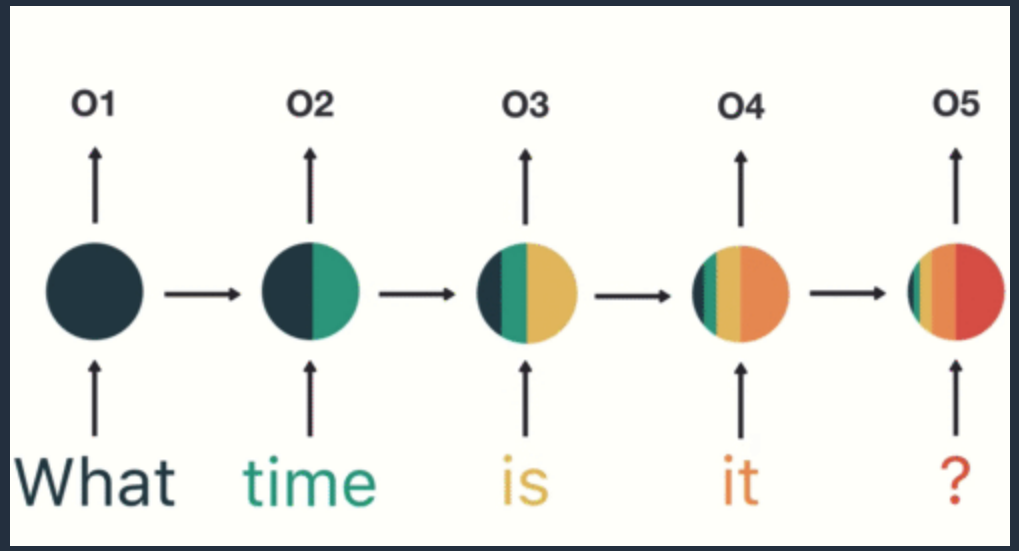
**Cons: It doesn't capture the sequence**

# Dive Deep

# RNNs & CNNs




# RNNs & CNNs

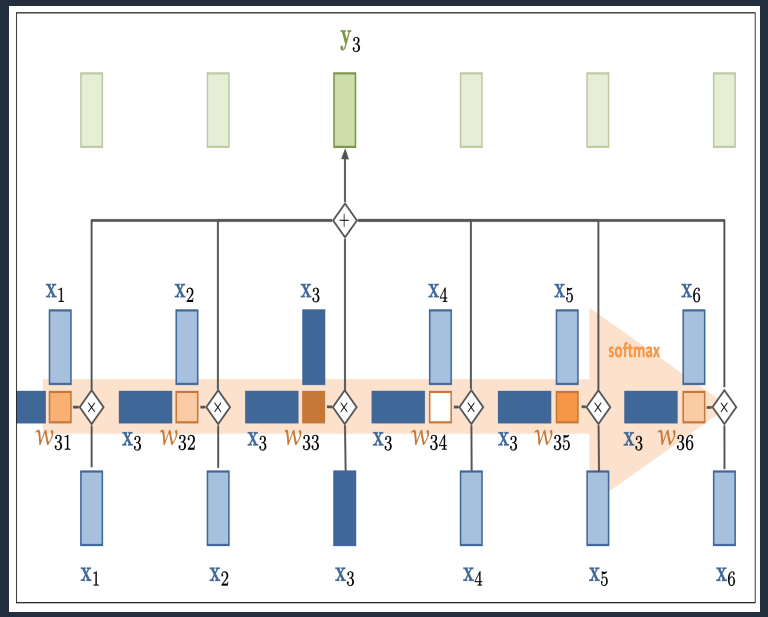


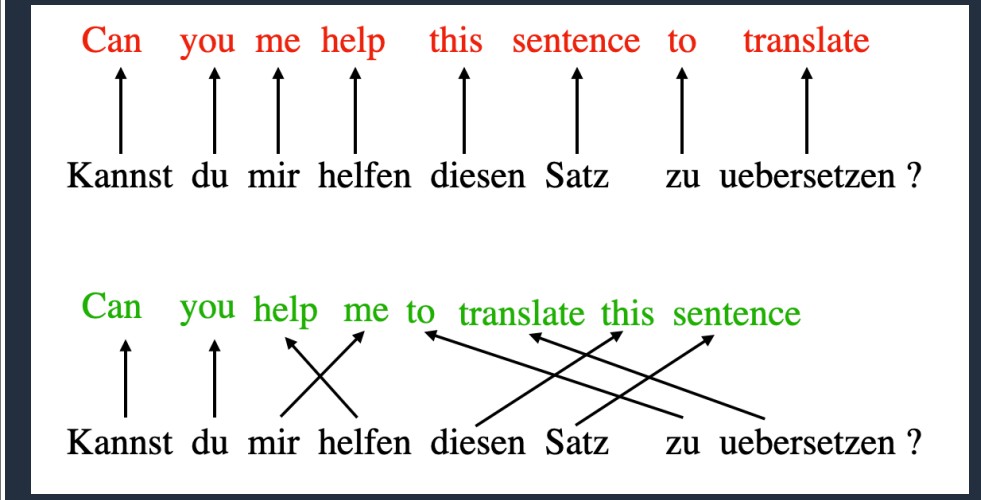

**Pros**: It captures the sequence

**Cons: It is either slow or limited by memory**

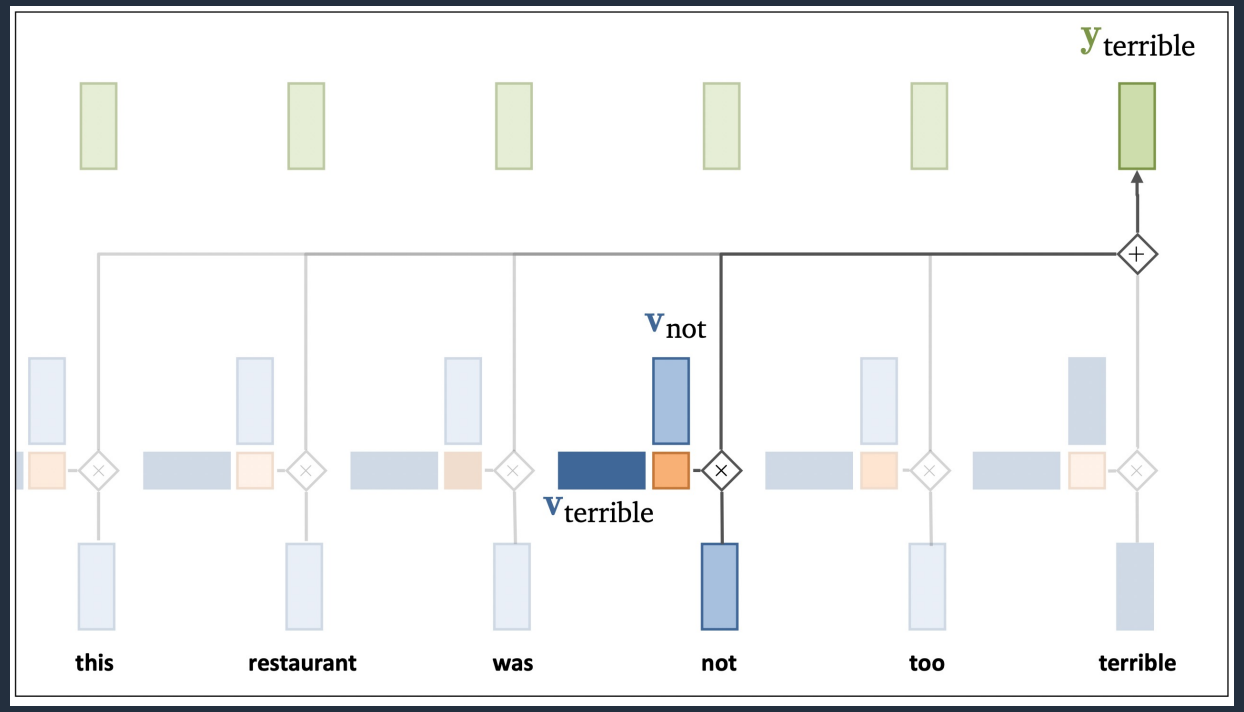
# Dive Deep

# Self-Attention

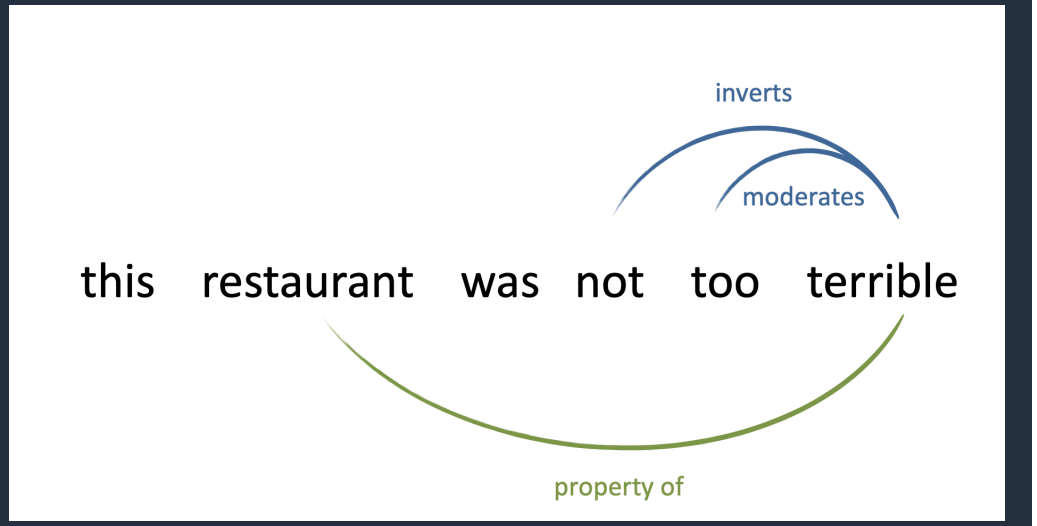


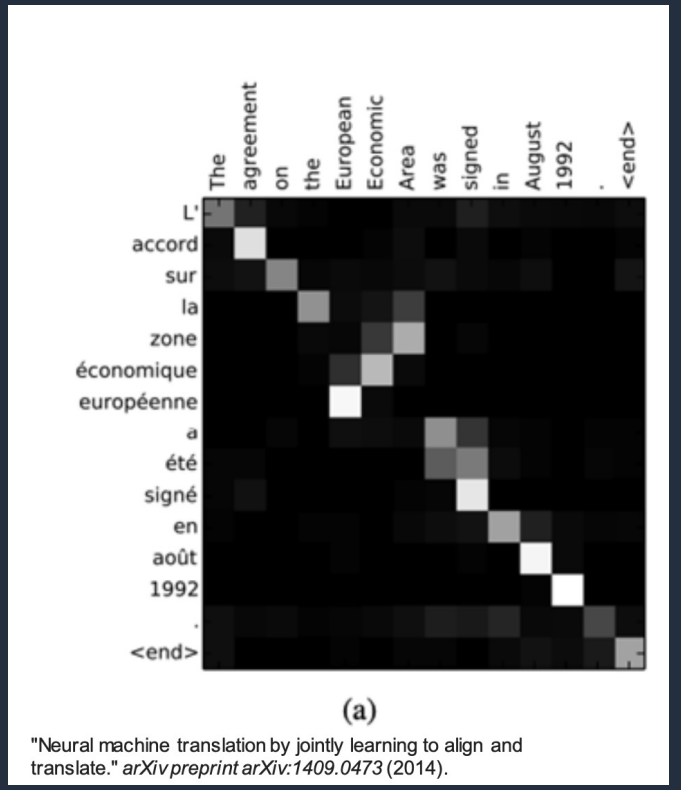



# Why attention is important



# Why is attention important?



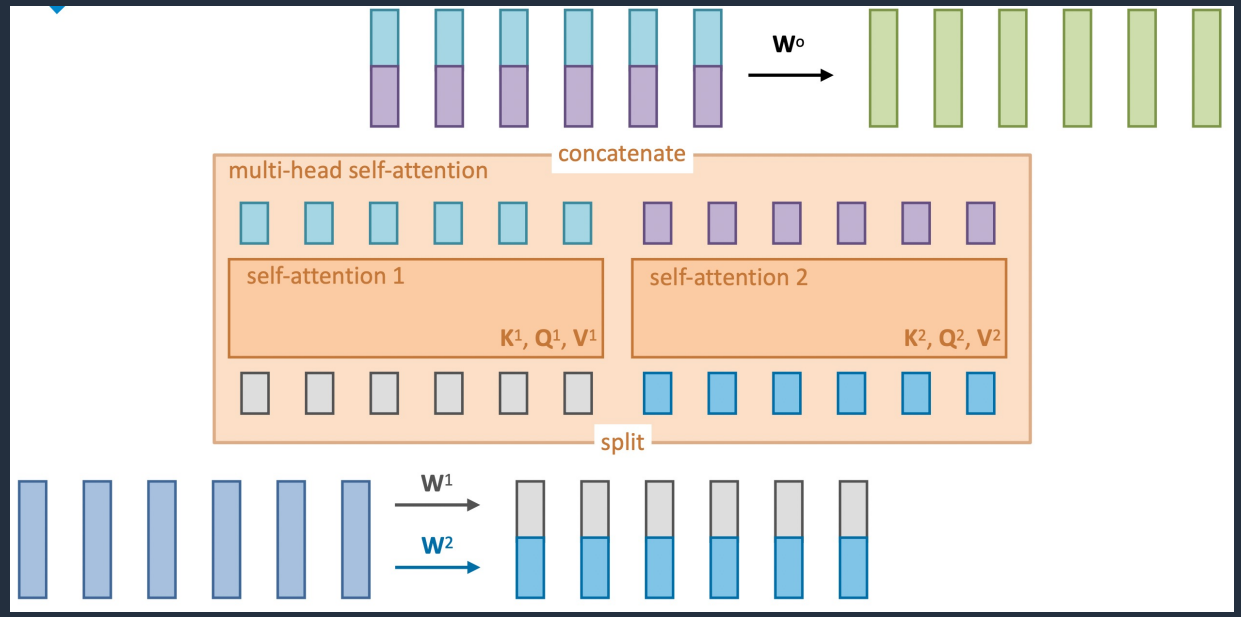

"Neural machine translation by jointly learning to align and translate." *arXiv preprint arXiv:1409.0473* (2014).

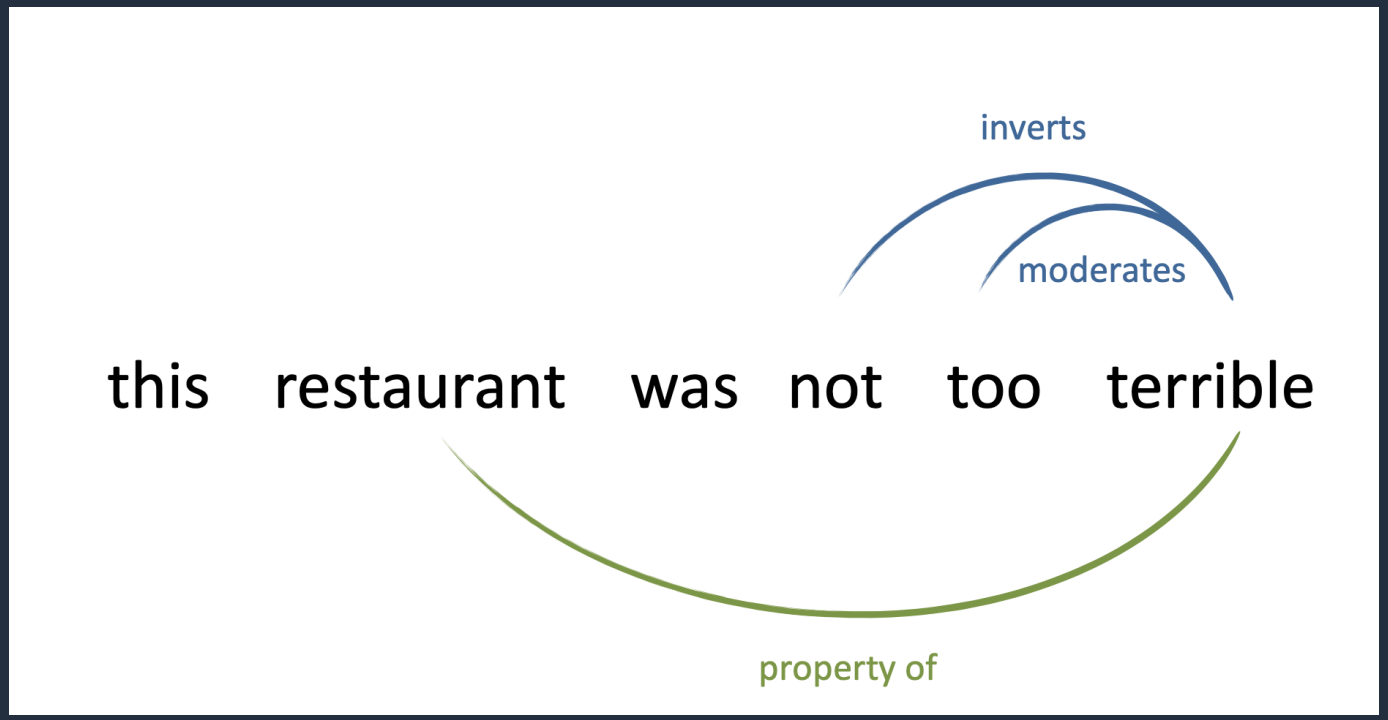
**Pros**: The model captures all words

**Cons: One attention mechanism is not enough**

# Dive Deep

# Multi-Head attention & Parallel Computations





**Pros**: The model pays attention to multi-logic

**Cons: It doesn't capture the word position**

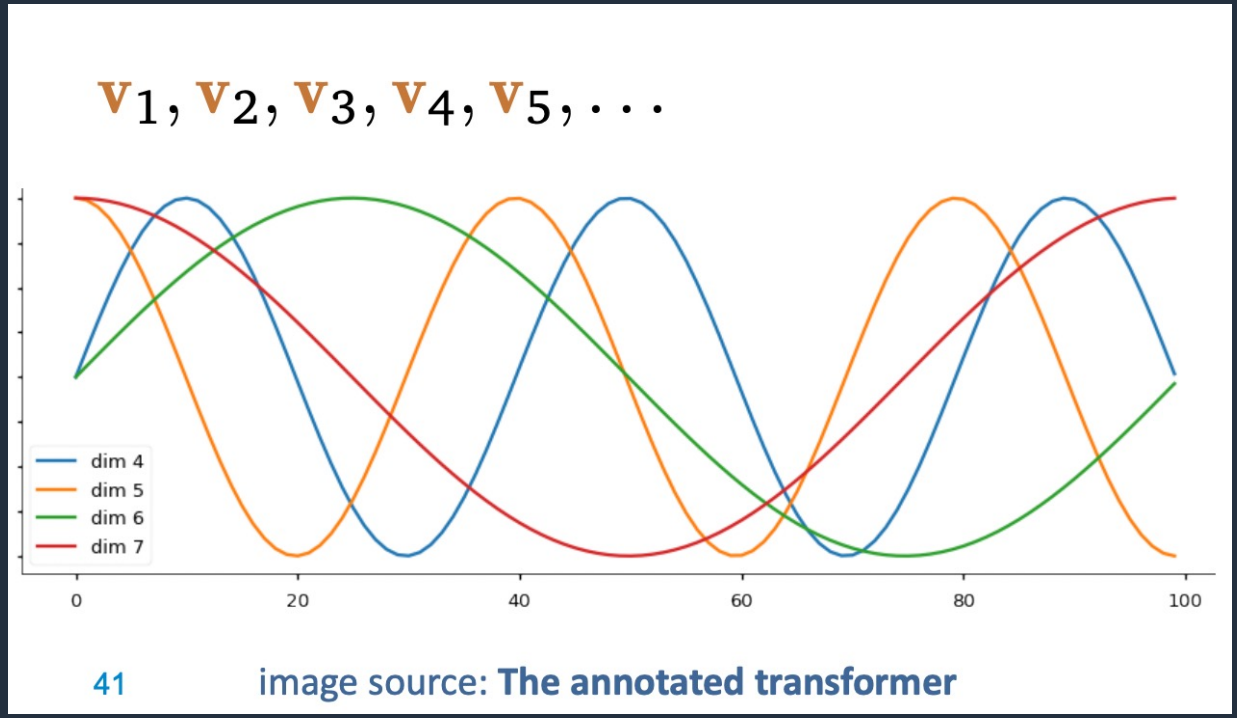
# Dive Deep

# What about Position

This is not a real restaurant, it’s a filthy burger joint.

This is not a filthy burger joint, it’s a real restaurant.

# Position Embeddings




41 image source: **The annotated transformer**

# Dive Deep

# Transformer Architecture

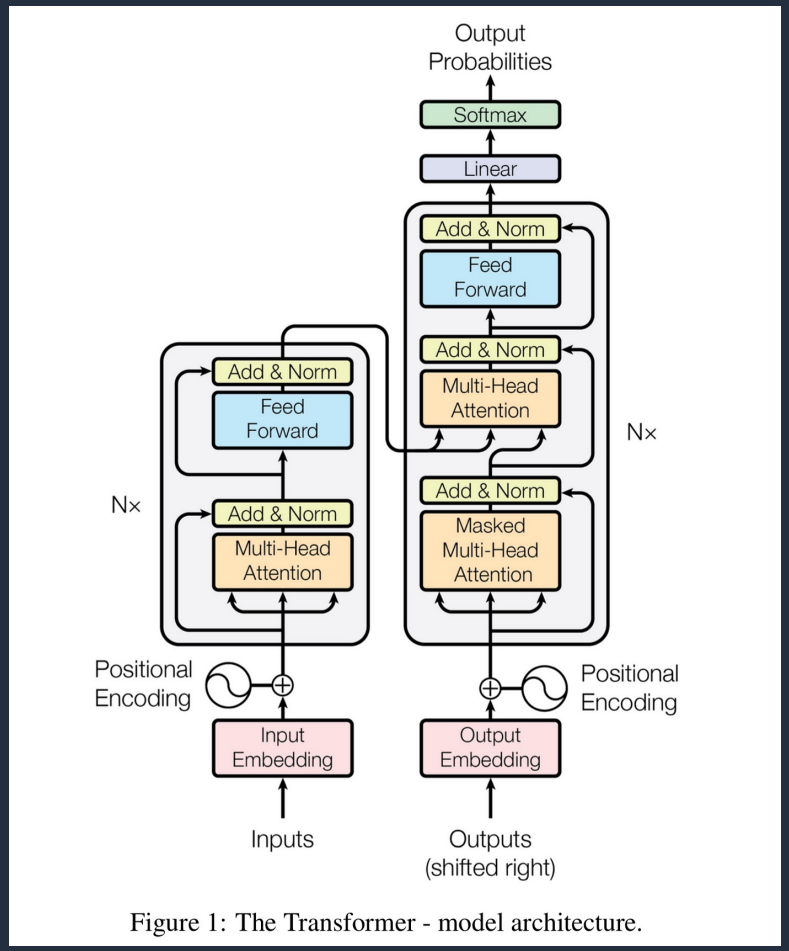



Figure 1: The Transformer - model architecture.

# I am lost. It’s OK.

# Methods to use generative AI

**Model provider**

Customers who build their own foundation models from scratch

**Model consumer**

Start with publicly or proprietary available foundation models and fine-tune to customize for their domain

**Application developer**

Make API calls to third party foundation model providers

# Low code option for model tuners and model consumers is to build on top of existing foundation models

Model provider

Model tuners

Model consumers

Build your own foundation models

Amazon SageMaker

Generative AI

Amazon CodeWhisperer

Build on top of existing foundation models

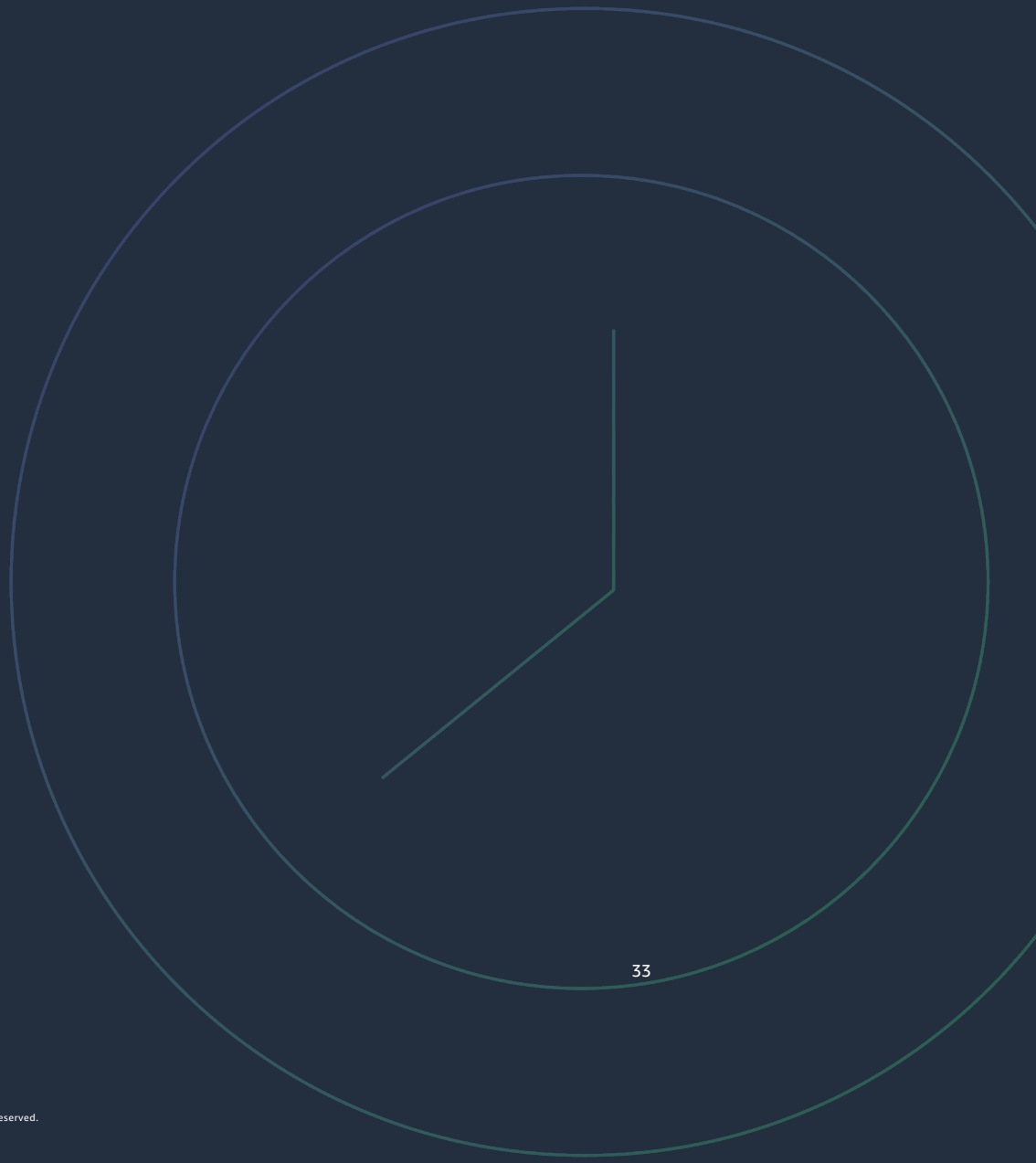
# Amazon SageMaker JumpStart

# Customer challenges

Getting started with ML takes

**too long...**

- Importing publicly available algorithms and models into SageMaker
- Maintaining and updating SageMaker-compatible scripts
- Setting up infrastructure
- Building NLP and vision models from scratch
- Model sharing and collaboration is done manually





# Amazon SageMaker JumpStart

ML hub with foundation models, built-in algorithms, and prebuilt ML solutions that you can deploy with just a few clicks

## Machine learning hub

Browse through 400+ built-in algorithms with pretrained models, pretrained foundation models, solutions, and example notebooks

## Pre-built training and inference scripts

Compatible with SageMaker and configurable with custom dataset

## UI as well as API-based

Use the user interface for single click model deployment or API for the Python SDK-based workflow

## Notebooks with examples

Jump into notebooks to use selected model with examples to guide you through the entire ML workflow

## Share and collaborate within your organization

Share models and notebooks with others within your organization, and allow them to train with their own data or deploy as-is for inferencing

# Why use foundation models on SageMaker JumpStart

**1**

**Choose foundation models offered by model providers**

AI21labs

Lighton
We bring Light to AI

stability.ai

co:here

alexa

**2**

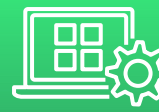
**Try out model and/or deploy**

Try out models via AWS Console

Deploy the model for inference using SageMaker hosting options includes single node

**3**

**Fine tune model and automate ML workflow**



Only selected models can be fine-tuned

Automate ML workflow

**Data stays in your account** including model, instances, logs, model inputs, model outputs

**Fully integrated** with Amazon SageMaker features



# SageMaker JumpStart models and features

## Publicly available

stability.ai

**Models**

SD XL, Upscaling, Inpainting

**Tasks**

Generate photo-realistic images from text input

Improve quality of generated images

**Features**

Fine-tuning on SD 2.1 model

alexa

**Models**

AlexaTM 20B

**Tasks**

Machine translation

Question answering

Summarization

Annotation

Data generation

**Models**

Falcon, OpenLLaMA, Flan, GPT NeoXT, BloomZ 176B

**Tasks**

Machine translation

Question answering

Summarization

Data generation

**Features**

Instruction and domain adaptation, RAG

## Proprietary models

co:here

**Models**

Cohere Command

**Tasks**

Text generation

Information extraction

Question answering

Summarization

Lighton

**Models**

Lyra-Fr 10B, Mini

**Tasks**

Text Generation

Keyword extraction

Information extraction

Question answering

Summarization

Sentiment analysis

Classification

AI21labs

**Models**

Jurassic-2 Ultra, Mid

**Tasks**

Text generation

Long-form generation

Summarization

Paraphrasing

Chat

Information extraction

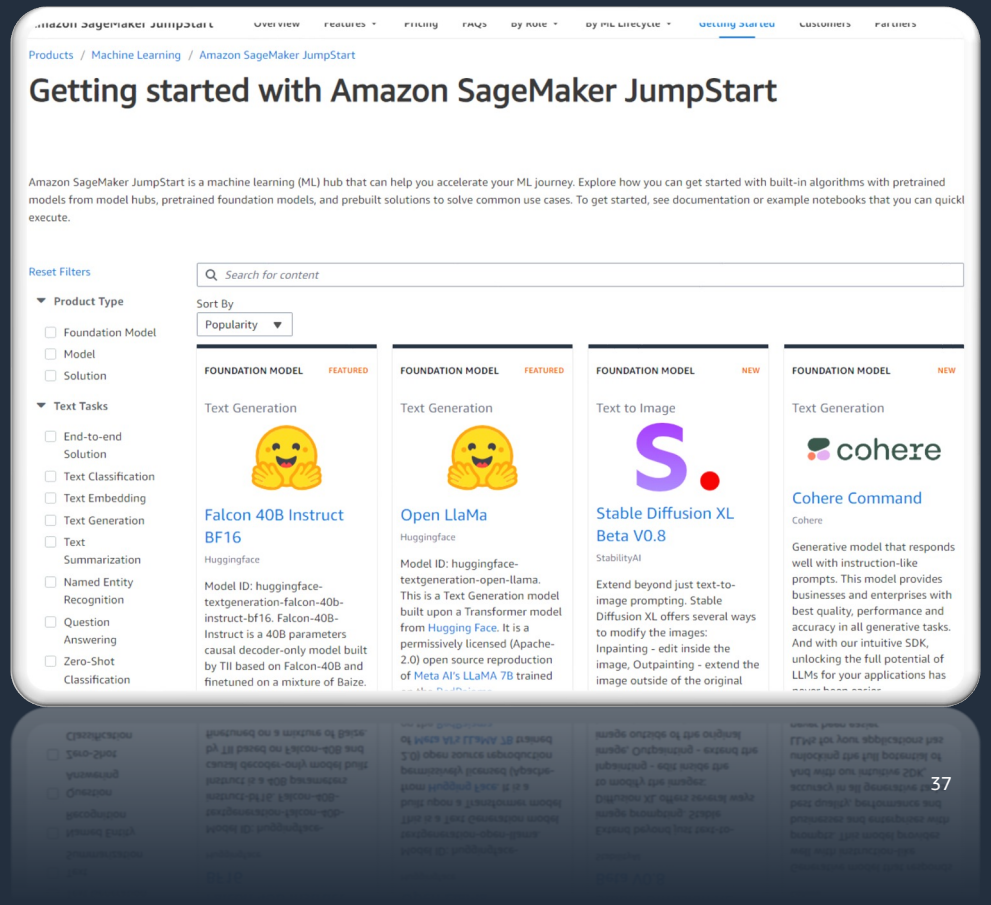
Question answering

Classification

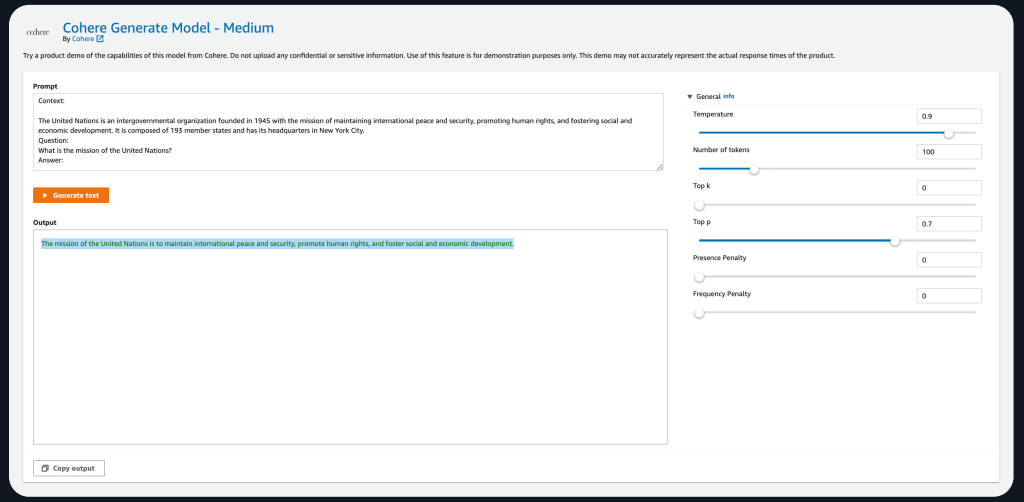


# Build on top of existing foundation models using Amazon SageMaker JumpStart

stability.ai
Lighton
AI21labs
co:here
alexa



# Try-out experience




- Try out the models and model prompts without running code or incurring costs
- Available for proprietary models in Top 10 in HELM benchmarks and public models for comparison purposes
- This is a shared environment in a SageMaker escrow account

# Choosing the right instance for hosting

| **Size of model** (# of parameters) | **Large** 3B–10B | **Mega** 11B–20B | **Massive** 100B+* |
|---|---|---|---|
| **Task Type** | Image generation<br>Simple text classification<br>(Short form) | Natural language understanding (NLU) | Natural language generation (NLG)<br>(long form) |
| **Minimum instance required** | p3.2xlarge<br>g5.2xlarge | p3.8xlarge<br>g5.12xlarge | p4de.24xlarge<br>p4d.24xlarge |
| **Pricing** | $4/hr<br>$2/hr | $15/hr<br>$9/hr | $47/hr<br>$38/hr |

Scale vertically (larger instances) to improve latency

Scale horizontally (more instances) to support higher traffic

*P4d instances will have limited availability, escalate to S-Team for support



# Instance type/size recommendation for models

| Model | Instance |
|---|---|
| Text Generation | |
| J2 Ultra | g5.48xlarge |
| J2 Mid | g5.12xlarge |
| Cohere Command Medium | g5.xlarge |
| Cohere Command XL | p4d.24xlarge |
| FLAN T5 XL | g5.2xlarge |
| FLAN T5 XXL | g5.12xlarge |
| FLAN UL2 | g5.12xlarge |
| GPT-J 6B | g5.12xlarge |
| GPT NeoX | g5.24xlarge |
| Image Generation | |
| Stable Diffusion 2.1 base | g5.2xlarge |
| SD Upscaling | g5.2xlarge |



# Selecting a foundation model

- Modality (text, image, multi-modal...)
- Training datasets (multi-lingual, Java...)
- Size
- Accuracy
- Throughput / latency
- Context length
- Inference cost

Center for Research on Foundation Models HELM Models Scenarios Results Raw runs

## Core scenarios

*The scenarios where we evaluate all the models.*

[ Accuracy | Calibration | Robustness | Fairness | Efficiency | General information | Bias | Toxicity | Summarization metr

## Accuracy

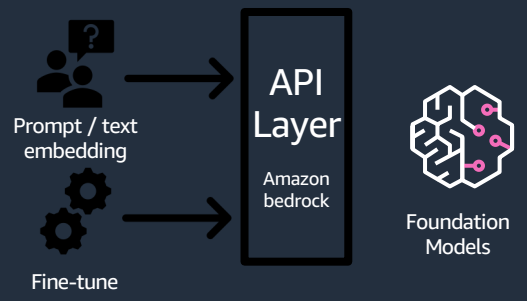
| Model/adapter | Mean win rate ↑ [ sort ] | MMLU - EM ↑ [ sort ] | BoolQ - EM ↑ [ sort ] | NarrativeQA - F1 ↑ [ sort ] | NaturalQuestions book) - F1 ↑ [ sort |
|---|---|---|---|---|---|
| Cohere Command beta (52.4B) | **0.93** | 0.452 | 0.856 | **0.752** | 0.372 |
| text-davinci-002 | 0.93 | 0.568 | 0.877 | 0.727 | 0.383 |
| text-davinci-003 | 0.898 | **0.569** | 0.881 | 0.727 | 0.406 |
| TNLG v2 (530B) | 0.855 | 0.469 | 0.809 | 0.722 | 0.384 |
| Anthropic-LM v4-s3 (52B) | 0.842 | 0.481 | 0.815 | 0.728 | 0.288 |
| J1-Grande v2 beta (17B) | 0.806 | 0.445 | 0.812 | 0.725 | 0.337 |
| Luminous Supreme (70B) | 0.783 | 0.38 | 0.775 | 0.711 | 0.293 |
| Cohere Command beta (6.1B) | 0.762 | 0.406 | 0.798 | 0.709 | 0.229 |
| Cohere xlarge v20221108 (52.4B) | 0.74 | 0.382 | 0.762 | 0.672 | 0.361 |
| OPT (175B) | 0.687 | 0.318 | 0.793 | 0.671 | 0.297 |
| Cohere xlarge v20220609 (52.4B) | 0.649 | 0.353 | 0.718 | 0.65 | 0.312 |
| davinci (175B) | 0.628 | 0.422 | 0.722 | 0.687 | 0.329 |
| GLM (130B) | 0.6 | 0.344 | 0.784 | 0.706 | 0.148 |
| J1-Jumbo v1 (178B) | 0.592 | 0.259 | 0.776 | 0.695 | 0.293 |
| Luminous Extended (30B) | 0.582 | 0.321 | 0.767 | 0.665 | 0.254 |
| BLOOM (176B) | 0.528 | 0.299 | 0.704 | 0.662 | 0.216 |
| OPT (66B) | 0.522 | 0.276 | 0.76 | 0.638 | 0.258 |

# Instance types for fine-tuning foundation models on SageMaker JumpStart

| | G4dn | P3 | P3dn | P4d |
|---|---|---|---|---|
| **Ideal for** | Accelerated training of small to medium sized models with less than 100M parameters | Training medium to large models with 100M to 300M parameters<br>Good for single node distributed training | Training large models with more than 300M parameters<br>Spot Training may provide better price-performance than P4d<br>Good for multi-node distributed training | Customer looking for best training performance on the cloud<br>Training large models with more than 300M parameters<br>Good for multi-node distributed training |
| **Key features** | 16 GB/GPU<br>PCIe only<br>25–50 Gbps networking<br>100 Gbps on bare-metal | 16 GB/GPU<br>200–300 GB/s NVLink (4, 8 GPUs)<br>10–25 Gbps networking | 32 GB/GPU<br>300 GB/s NVLink (8 GPUs)<br>100 Gbps networking | 40 GB/GPU<br>600 GB/s NVLink (8 GPUs)<br>400 Gbps networking |
| **GPU config** | 1, 4, or 8 NVIDIA Tesla T4s | 1, 4, or 8 NVIDIA Tesla V100s | 8 NVIDIA Tesla V100s | 8 NVIDIA Tesla A100s (latest) |
| **Recent launches** | Habana Gaudi | Trainium | g5 | p4de* |

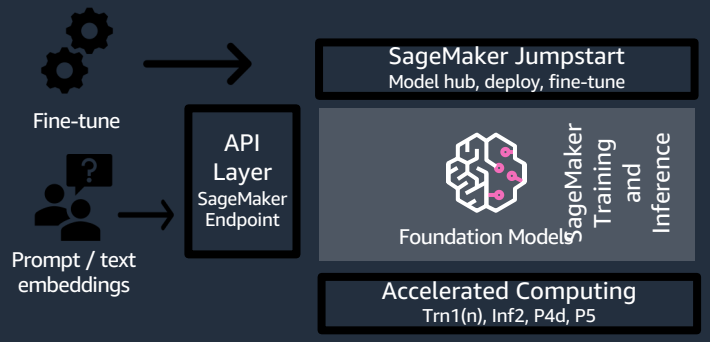
Broadest and most complete set of Distributed Training Infrastructure choices

# How do I access foundation models?



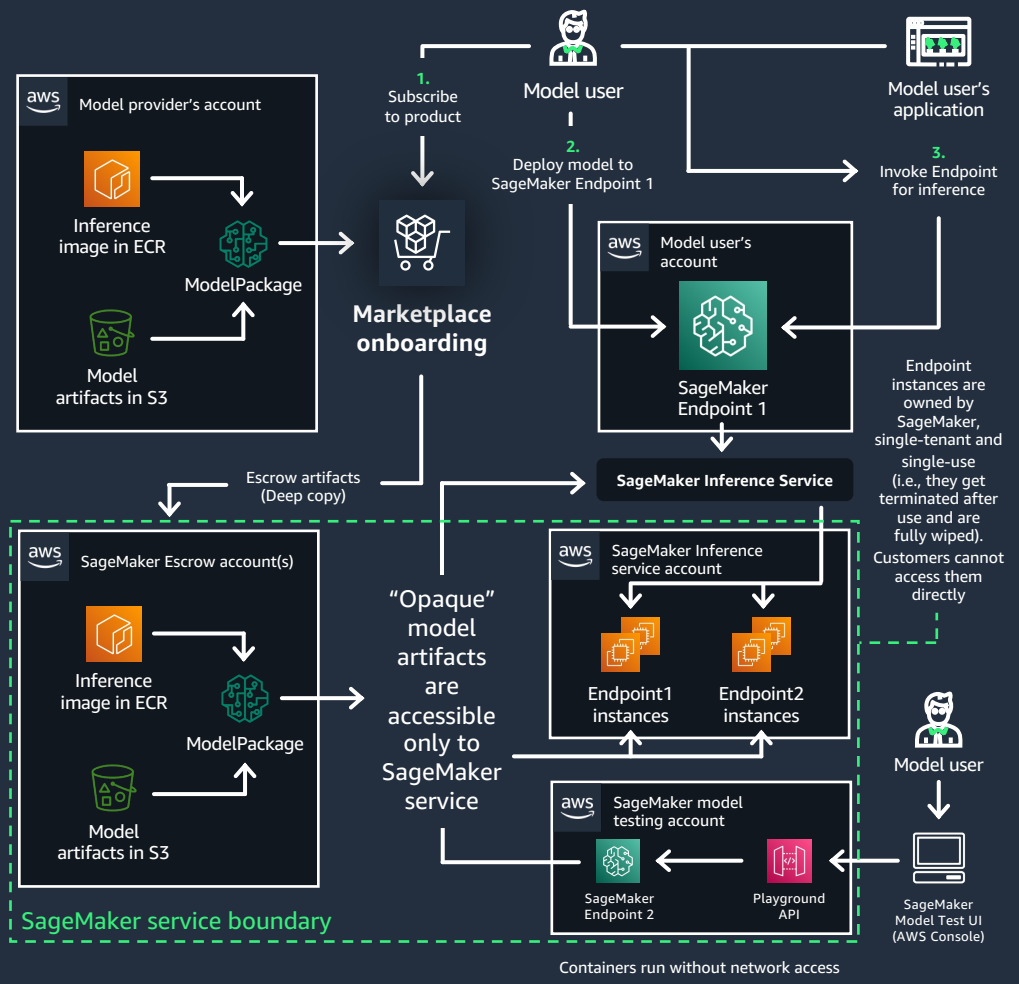

## Amazon Bedrock

- The easiest way to build and scale generative AI applications with foundation models (FMs)
- Access directly or fine-tune foundation model using API
- Serverless




## Amazon SageMaker JumpStart

- Machine learning (ML) hub with foundation models, built-in algorithms, and prebuilt ML solutions that you can deploy with just a few clicks
- Deploy FM as SageMaker Endpoint (hosting)
- Fine-tuning leverages SageMaker Training jobs
- Choose SageMaker managed accelerated computing instance



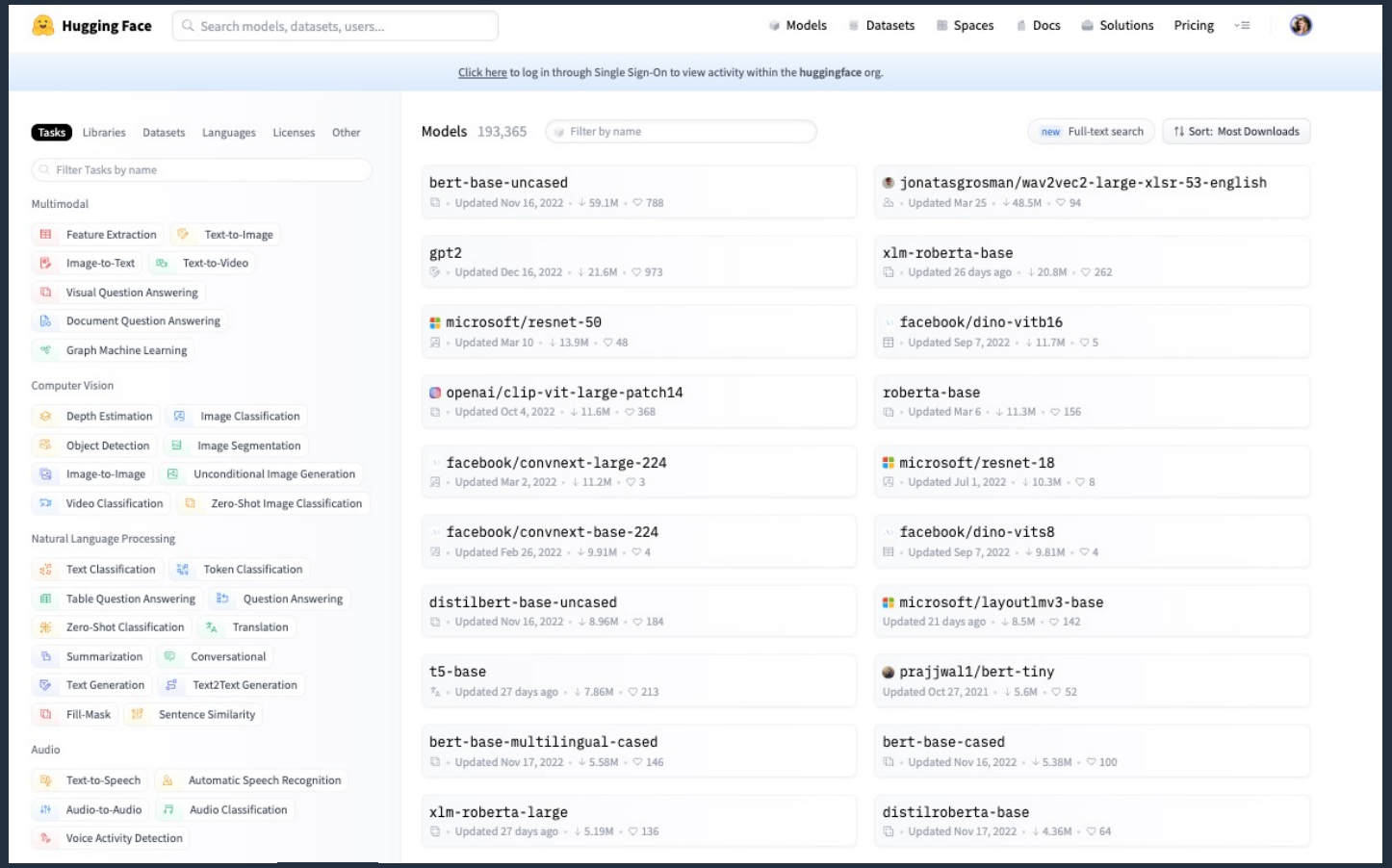

# SageMaker JumpStart protects your data and model provider IP

- Proprietary model package and endpoint is hosted in SageMaker owned escrow account
- Containers have no outbound network access; user data and model provider IP is protected the same time
- No data is used to update/train the base model that JumpStart provides to customers



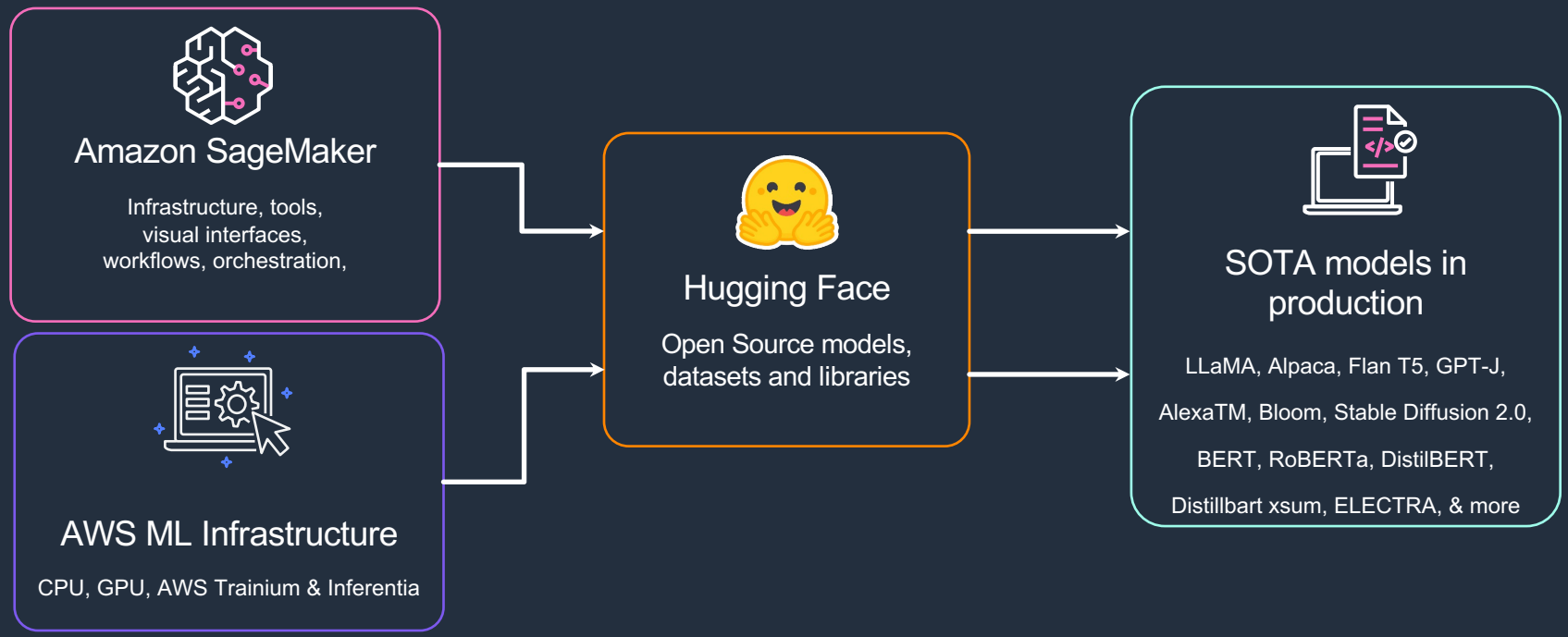
# HuggingFace

# Hugging Face: the largest collection of open source models and datasets




- 200,000+ pre-trained models
- 30,000+ public datasets
- 10,000+ organizations
- 160+ languages
- 500,000+ daily active users

# Hugging Face and AWS collaborate to simplify state-of-the-art AI



# Hugging Face open source libraries

- Transformers: Transformer models for Pytorch, TensorFlow, and JAX
- Diffusers: image and audio generation models for PyTorch
- Accelerate: simple distributed training (CPU, GPU, TPU) for PyTorch
- Peft: Parameter Efficient Fine-Tuning lets you train larger models on the same GPU
- SetFit: few-shot learning for Sentence Transformers

- Optimum: hardware acceleration for Transformers and Diffusers
  - Optimum Intel: Intel Neural Compressor, Intel OpenVINO
  - Optimum Habana: training and inference for Habana Gaudi/Gaudi2
  - Optimum Neuron: AWS Trainium and Inferentia2



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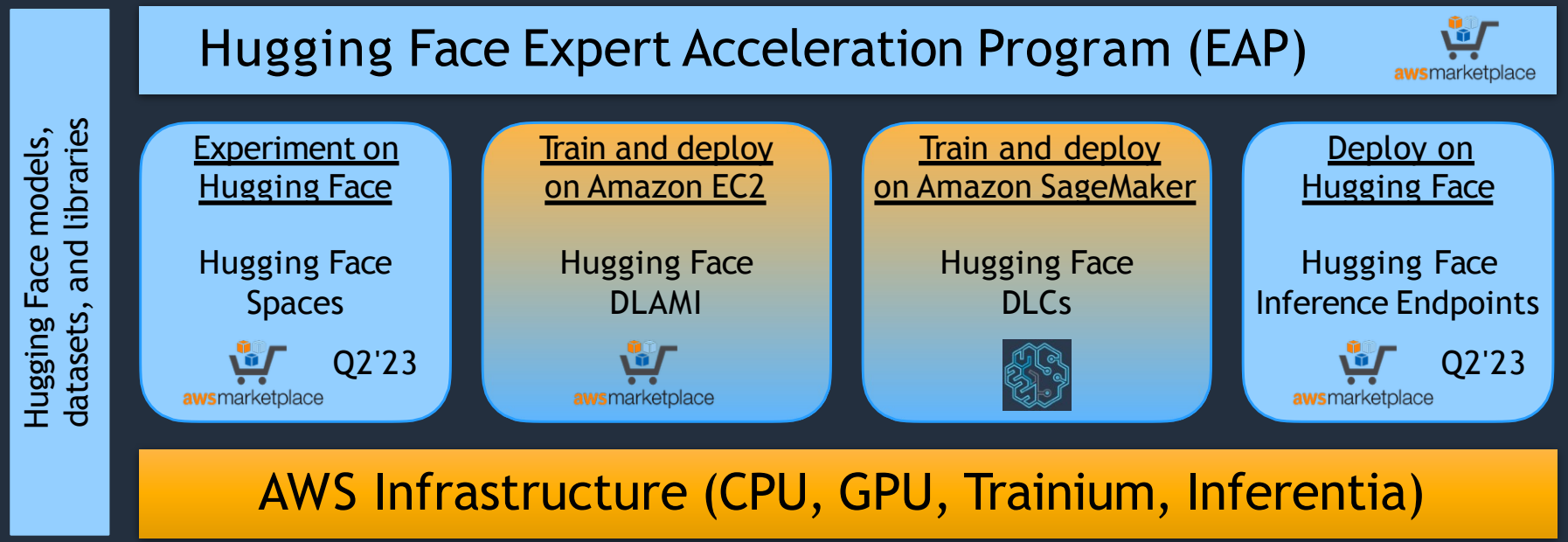
# End-to-end ML with Hugging Face on AWS



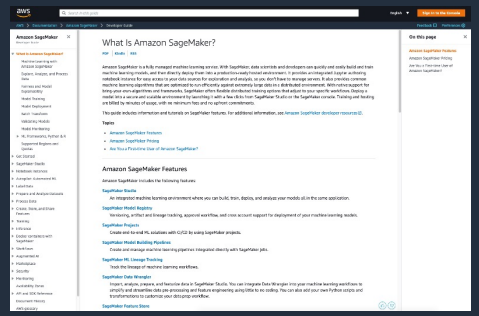



# Technical resources

## Hugging Face documentation

Documentation

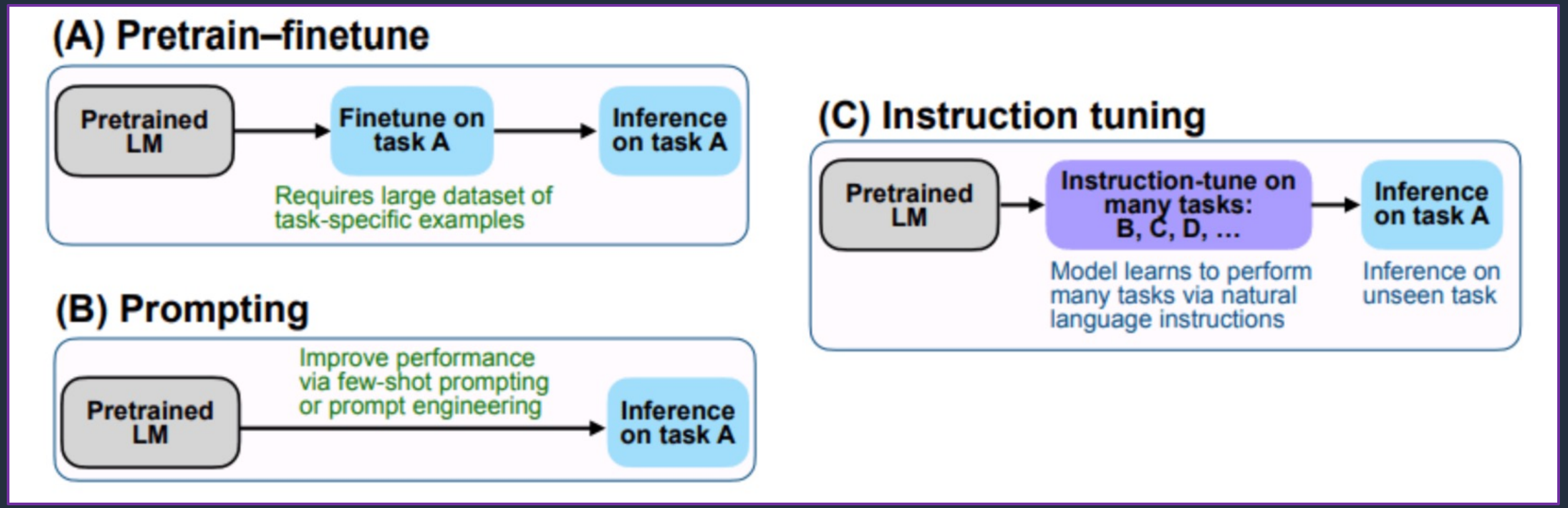
## SageMaker documentation




Documentation

# Best practices for Model Tuning

# Learning Paradigms



# Using Foundation Models – User Journey Example

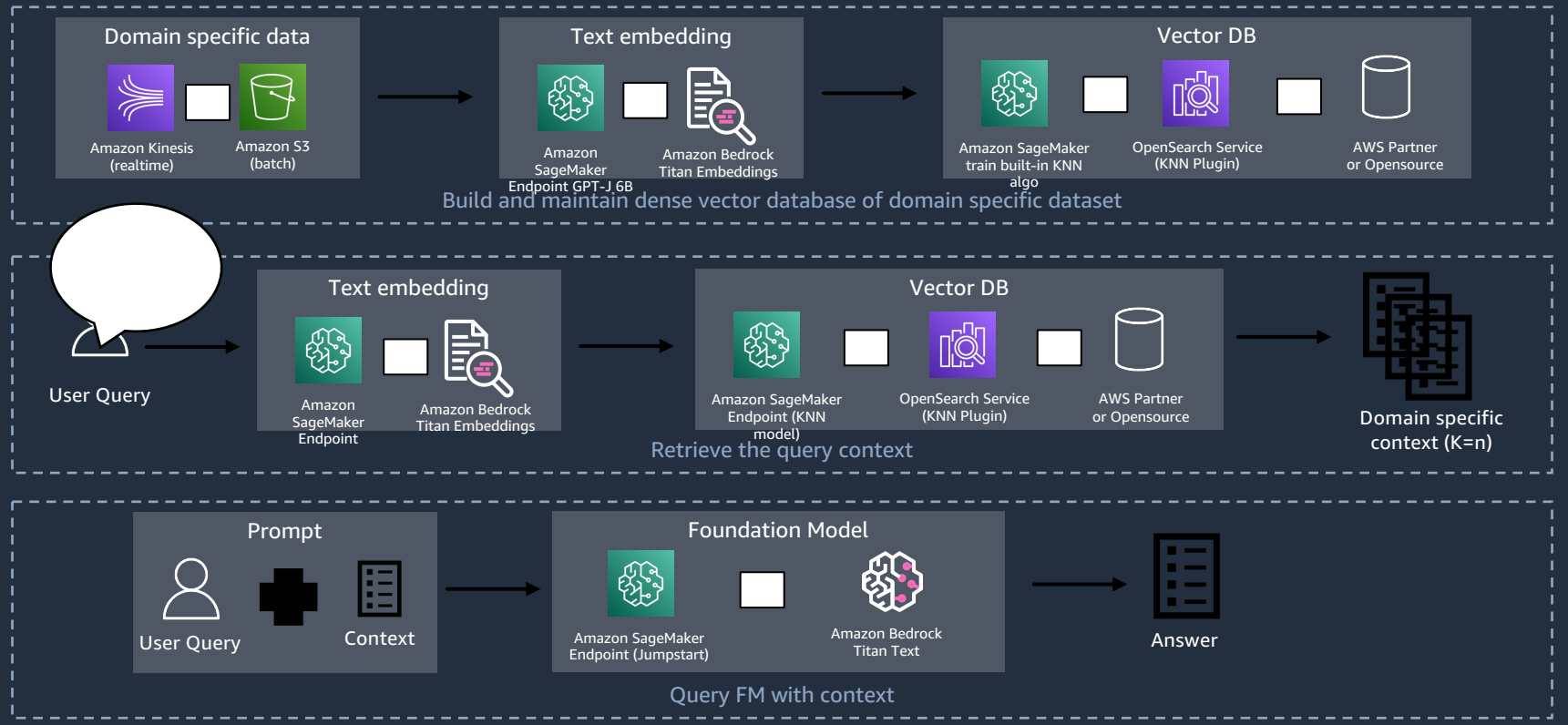

Q&A on proprietary or domain specific data

(e.g., internal Wiki, FAQs, product documentation)

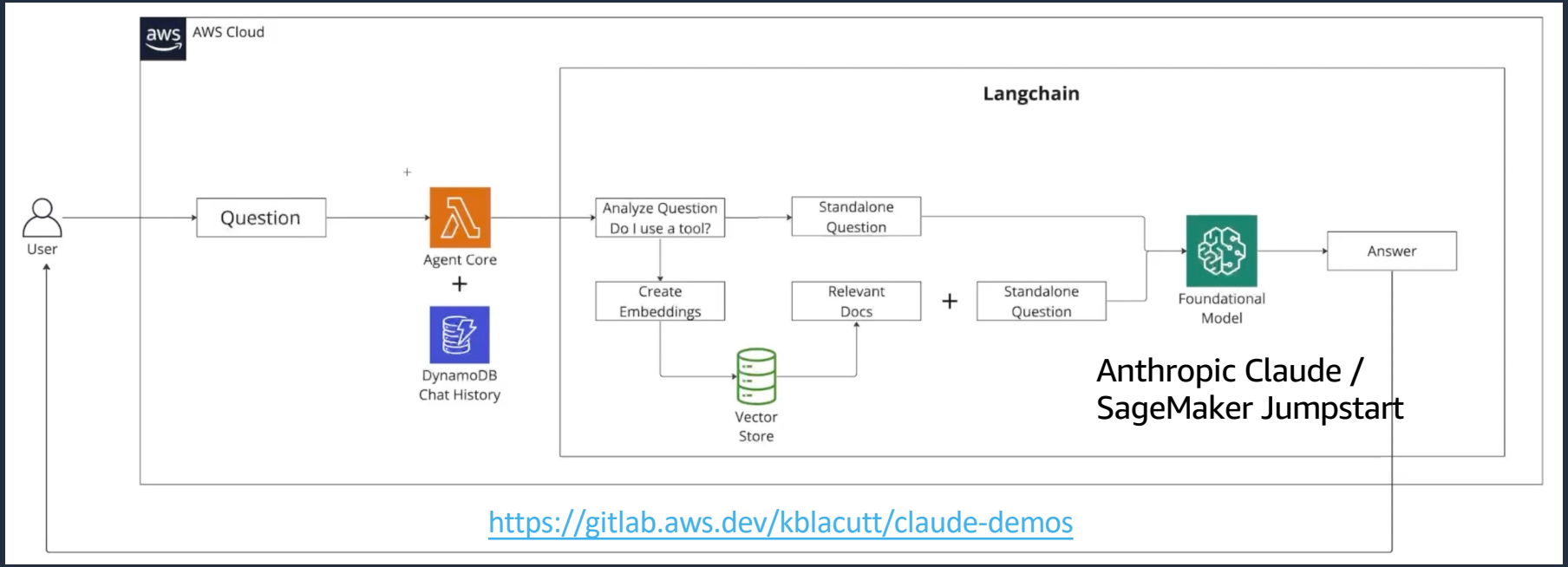
# Knowledge Augmentation

# Retrieval-Augmented Generation (RAG)

## EXAMPLE ARCHITECTURE



Bored of going through transaction history?
Now you can talk literally talk to your bank account!




Credit: Kenton Blacutt

# Examples: RAG and domain adaptation/fine-tuning

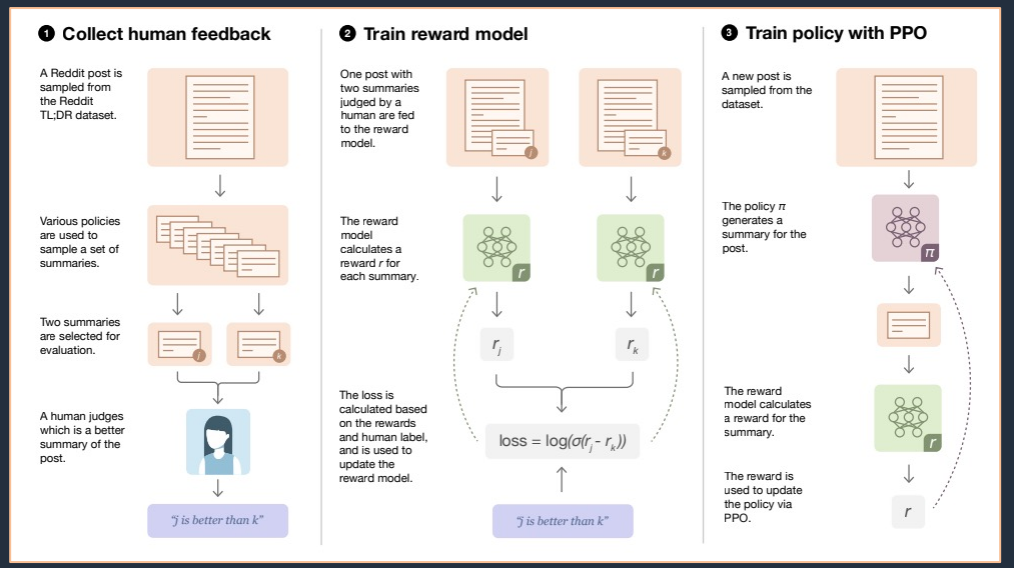
QUESTION AND ANSWER USING DOMAIN SPECIFIC DATASET

- Amazon SageMaker Jumpstart + VectorDB as Amazon SageMaker KNN and Opensource (langchain)
- Amazon SageMaker Jumpstart + VectorDB as Amazon OpenSearch
- Domain Adaption Fine Tuning using Amazon SageMaker JumpStart on Financial Data

# Reinforcement Learning from Human Feedback (RLHF)

- ***Why use RL with human feedback for LLMs?***
  - Reduces the need for *explicit supervision*
  - Improves the model's ability to generate more *helpful* and *context-aware* responses
  - Enables fine-tuning to *align* with human values and preferences
- ***Process***
  1. Gather model-generated responses
  2. Obtain human rankings based on quality
  3. Train a reward model using ranked data
  4. Predict reward values for potential responses
  5. Fine-tune with *Proximal Policy Optimization* (PPO)

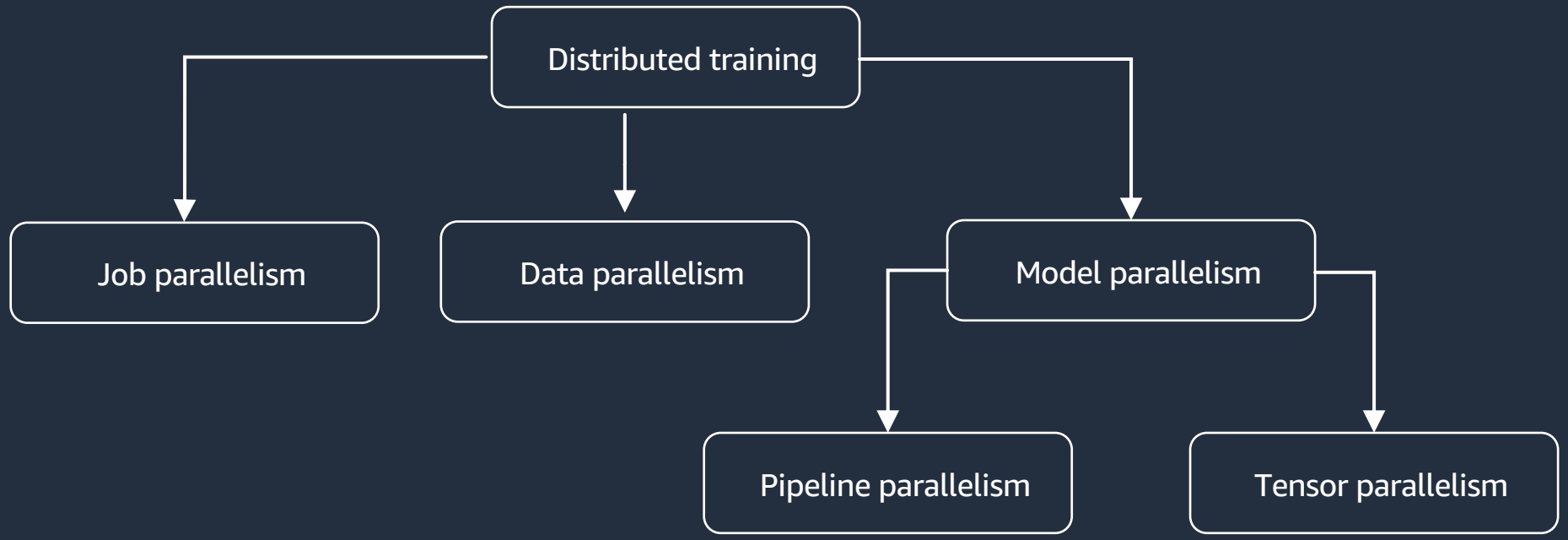
**On Roadmap**



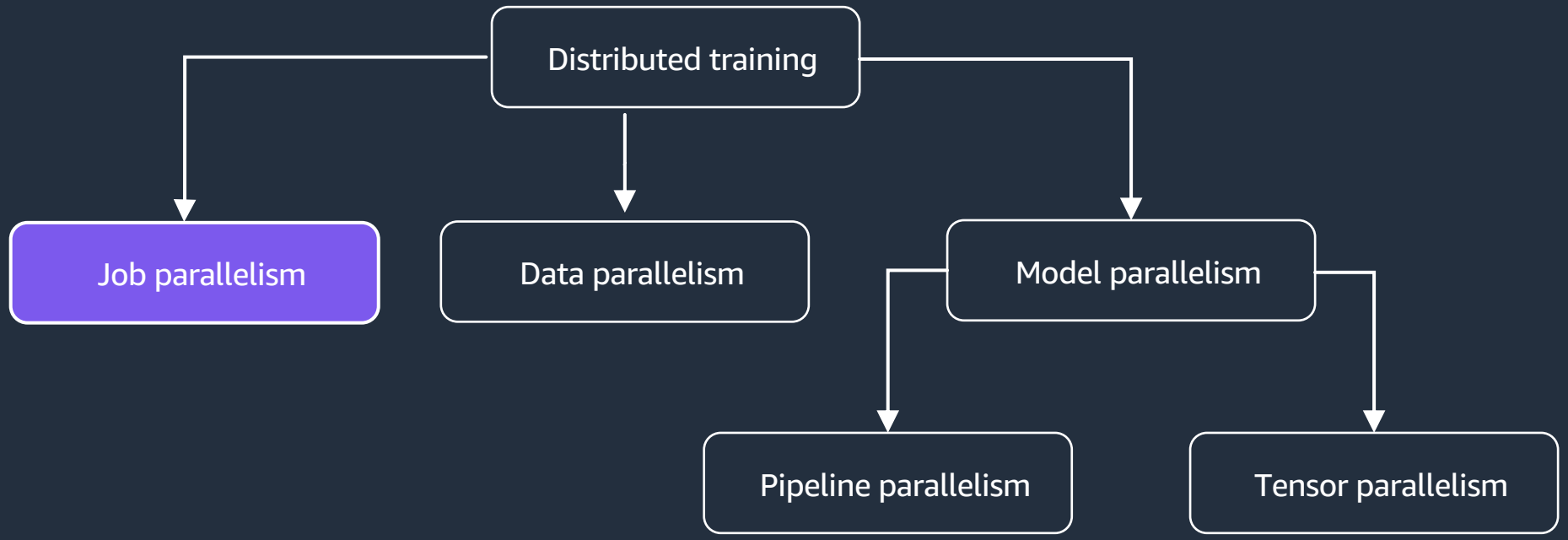
# Amazon Distributed Training – for Model Tuners and Providers

# Distributed Training Types

# There are many kinds of distributed training



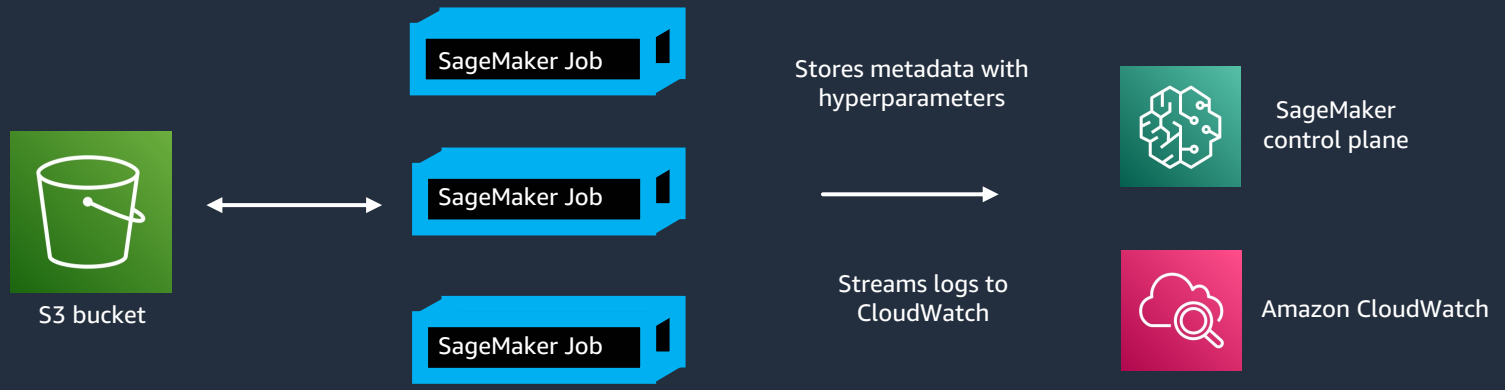

# There are many kinds of distributed training



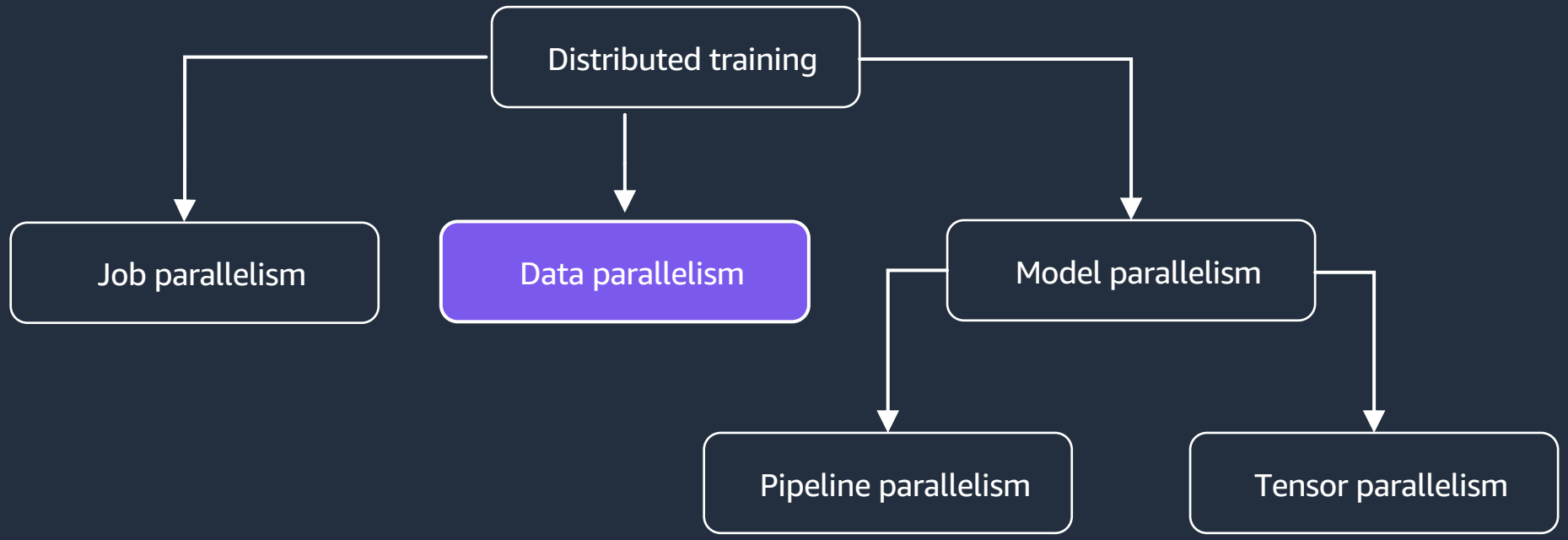

# Train with parallel jobs at high frequency

1. Each job can train as many models as you need.
2. You can use ***warm pools*** to retrain as quickly as possible

```
for model in list_of_models:
        s3_input = get_data(model)
        s3_output = get_location(model)
        estimator = get_estimator(model, s3_output)
        estimator.fit(s3_input, wait=False)
```



# There are many kinds of distributed training




# Data Parallelism

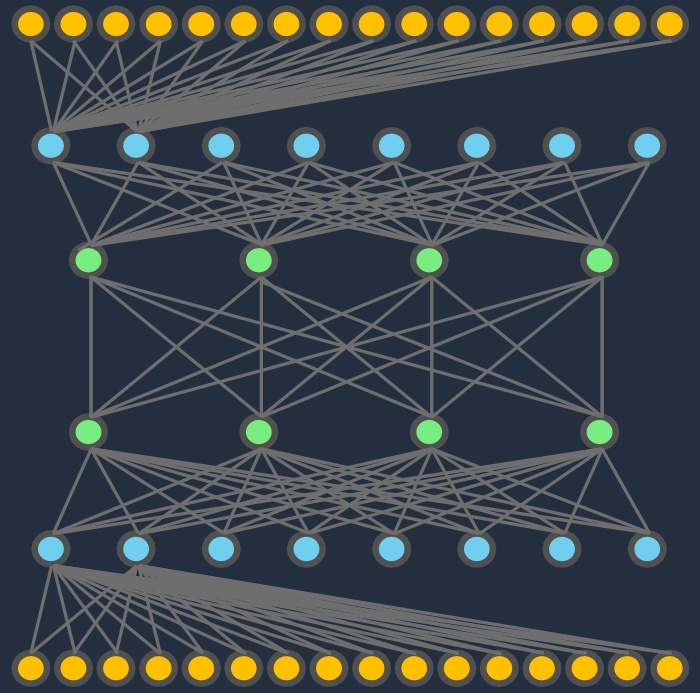
# Amazon SageMaker Distributed Data Parallel

Optimized backend for distributed training of deep learning models in TensorFlow, PyTorch

Accelerates training for network-bound workloads

Built and optimized for AWS network topology and hardware

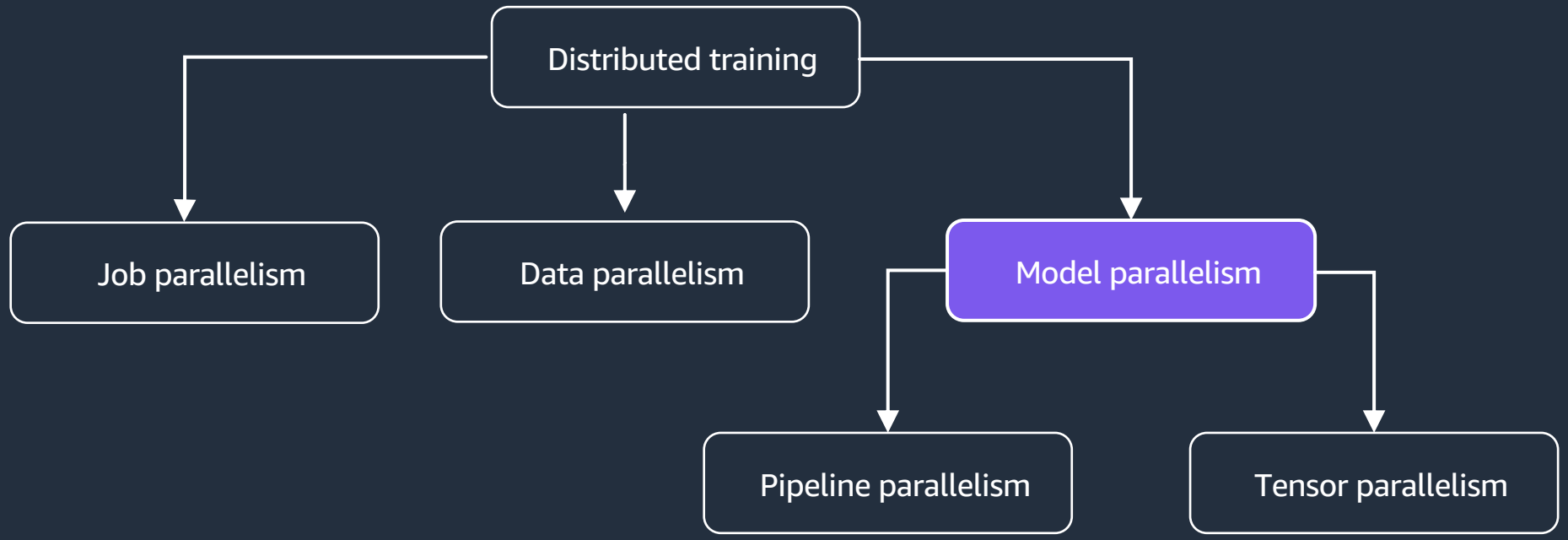
20%–40% faster and cheaper than NCCL and MPI-based solutions. **Best performance on AWS for large clusters.**



# Amazon SageMaker Distributed Data Parallel

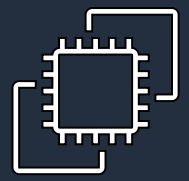
| Model | Setup | Throughput | | | Scaling Efficiency | | |
|---|---|---|---|---|---|---|---|
| | | PT-DDP | SageMaker | Speed up | PT-DDP | SageMaker | Improvement |
| BERT Large (seqs/sec) | 2 node p3dn.24xl | 1752 | 2479 | 41% | 64% | 90% | 26% |
| | 4 node p3dn.24xl | 3017 | 4603 | 52% | 55% | 84% | 29% |
| | 8 node p3dn.24xl | 7409 | 8551 | 15% | 67% | 78% | 11% |
| MaskRCNN (samples/sec) | 2 node p3dn.24xl | 152 | 158 | 4% | 82% | 85% | 3% |
| | 4 node p3dn.24xl | 258 | 307 | 19% | 70% | 83% | 13% |
| | 8 node p3dn.24xl | 545 | 617 | 13% | 74% | 84% | 10% |

# There are many kinds of distributed training




# Model parallel, think “massive models”

# Model parallelism on Amazon SageMaker (SMP)



**Automated model partitioning**

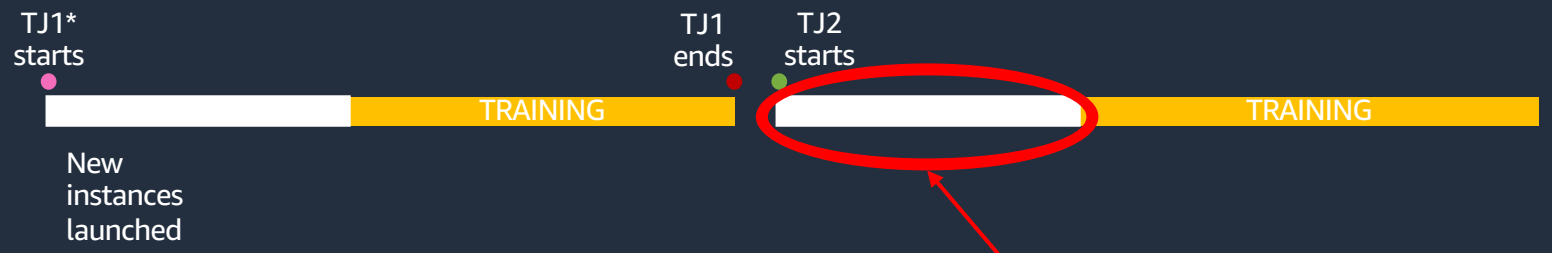
**Interleaved pipelined training**

**Managed SageMaker training**

**Clean framework integration**

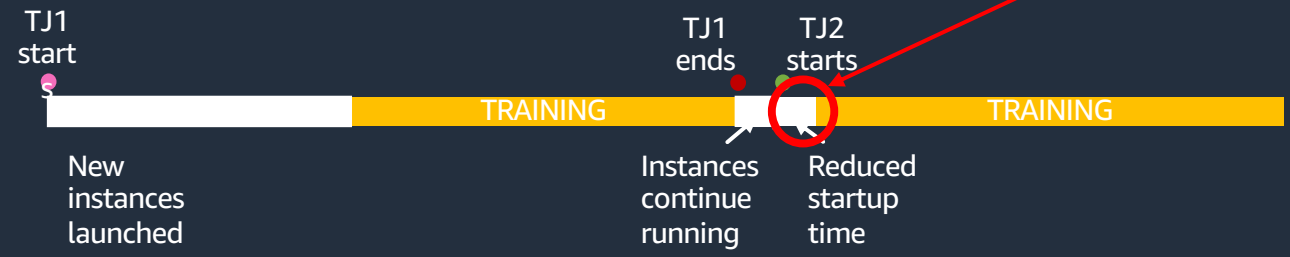
# Warm Pools: Faster startup time

Before: Multi-minute wait between script updates




After: Multi-*second* wait between script updates

Keep_alive_period_in_seconds=600

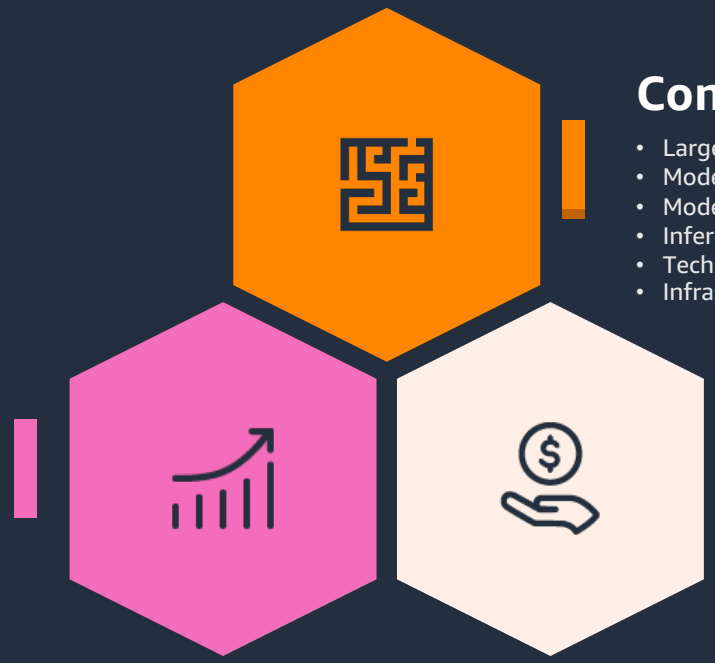



*TJ=Training Job



# Deploy large models

# Large model hosting challenges



## Complexity

- Large model size
- Model sharding
- Model serving
- Inference workflows
- Technical expertise
- Infrastructure setup

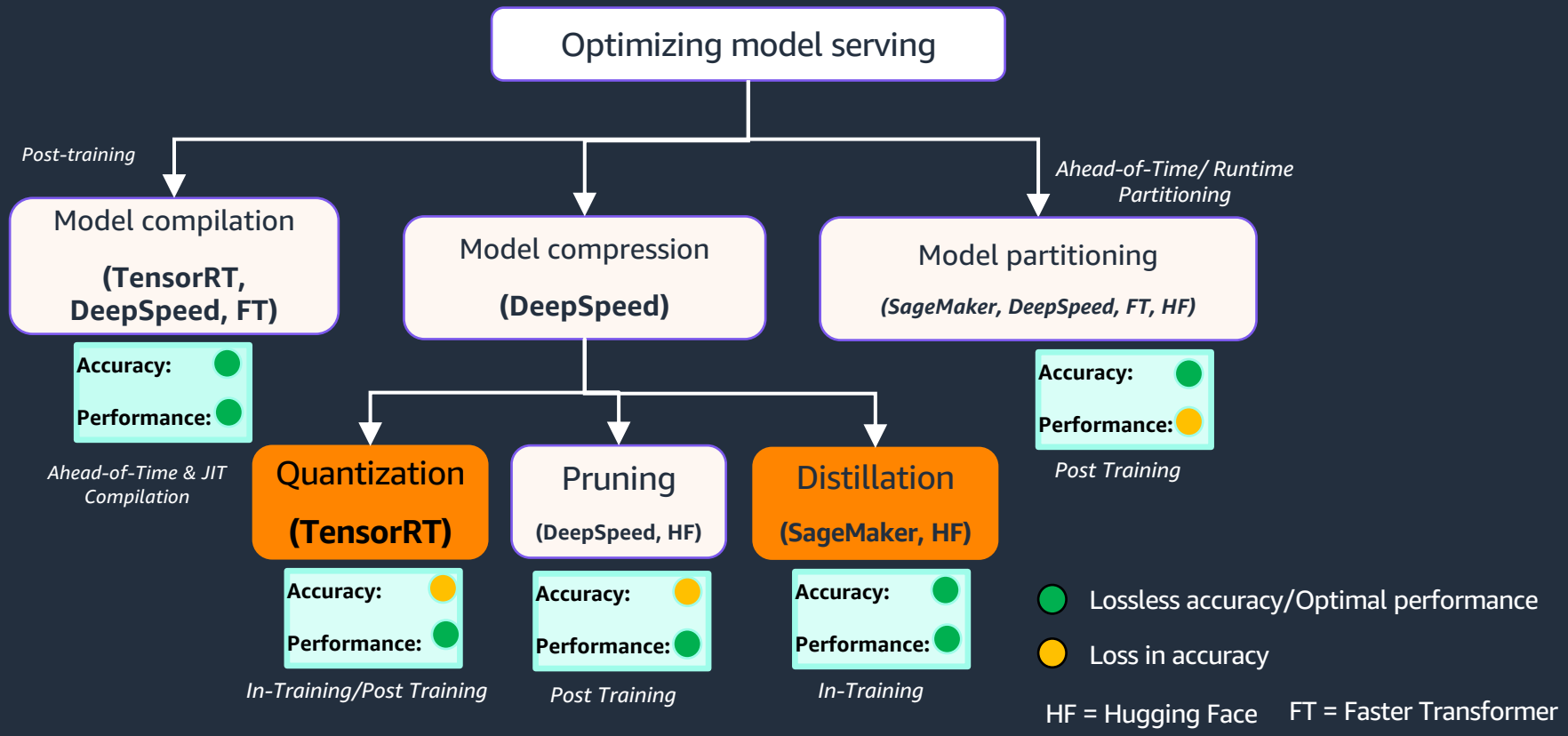
## Performance

- Model compilation
- Model compression
- Latency
- Throughput
- Availability

## Cost

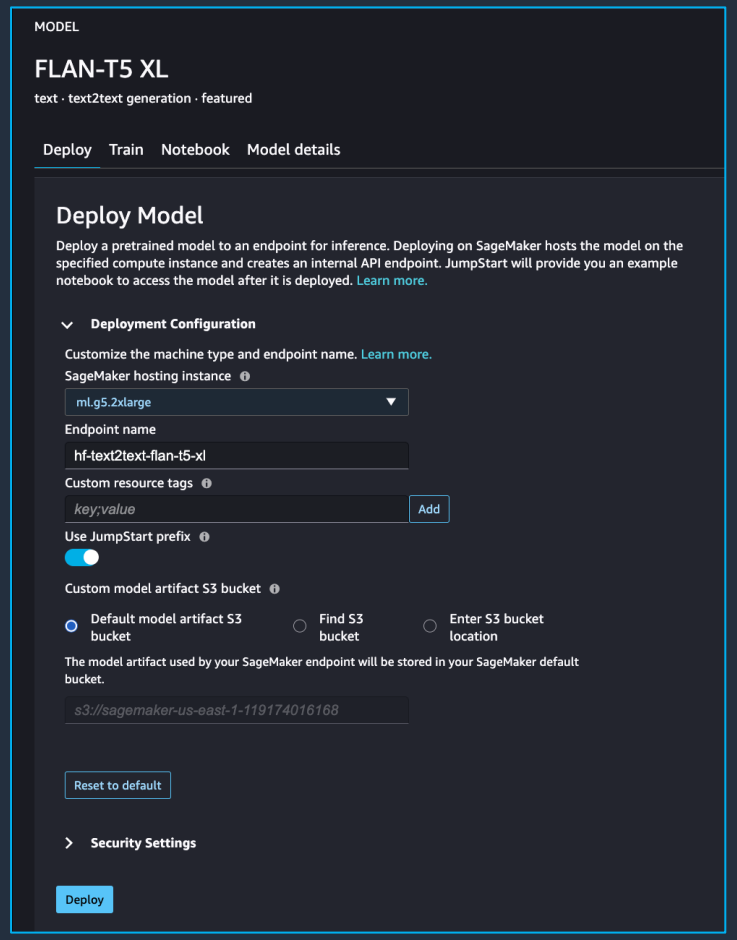
- Model compilation
- Model hosting cost
- Operational overhead
- Number of models to deploy and manage

# Large model inference optimization



# Hosting Large Language Models

- ***Scalability & Cost Efficiency:*** Sagemaker JumpStart endpoints scale to handle any traffic, with a pay-as-you-go model
- ***Rapid Deployment & High Availability:*** Deploy ML models quickly, with built-in failover for high availability
- ***Real-Time/Batch Inference & Monitoring:*** Perform real-time and batch inference and monitor your model's performance
- ***GPU Support & High-Performance:*** Optimized performance for deep learning models and low-latency capabilities
- ***Model Versioning & A/B Testing***: Switch between versions and compare performance with A/B testing
- ***Autoscaling & Routing:*** Autoscale based on policies and route traffic based on model weights
- ***Seamless Integration:*** Integrate with other AWS services and SageMaker components to build complex NLP pipelines



IBM

# Thank you

Partha Dey

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AWS