Topic: Partial Freezing of MLMs for PoS Tagging: A Case of Naija Pidgin

```
!pip -q install datasets transformers conllu torch
```

```
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```

Task 1: Dataset Preparation and Baseline Model Training

Loading Data

```
import random
import numpy as np
import torch

SEED = 42

random.seed(SEED)
np.random.seed(SEED)
torch.manual_seed(SEED)
torch.backends.cudnn.deterministic = True
```

```
import requests, zipfile, io, os

# GitHub raw URL (direct to the ZIP)
url = "https://github.com/johnemekaeze/PoS-Tagging-MLMs-Partial-Freezing/raw/main/data/ud-treebanks-v2.16-subset.zip"

# Download and extract to a folder
response = requests.get(url)
z = zipfile.ZipFile(io.BytesIO(response.content))
z.extractall("ud_subset")  # this creates a folder with all sub-treebanks
```

```
import os

root_path = "ud_subset/ud-treebanks-v2.16-subset"
treebanks = sorted(os.listdir(root_path))
print("Available treebanks:")
treebanks
```

```
Available treebanks:
['UD_English-Atis',
 'UD_English-CHILDES',
 'UD_English-CTeTex',
 'UD_English-ESLSpok',
 'UD_English-EWT',
 'UD_English-GENTLE',
 'UD_English-GUM',
 'UD_English-GUMReddit',
 'UD_English-LinES',
```

```
      'UD_English-ParTUT',
      'UD_Hausa-NorthernAutogramm',
      'UD_Hausa-SouthernAutogramm',
      'UD_Naija-NSC',
      'UD_Yoruba-YTB']


from conllu import parse_incr

def load_conllu_sentences(path):
    data = []
    with open(path, "r", encoding="utf-8") as f:
        for tokenlist in parse_incr(f):
            tokens = [token["form"].lower() for token in tokenlist if type(token["id"]) == int]
            upos   = [token["upos"] for token in tokenlist if type(token["id"]) == int]
            data.append((tokens, upos))
    return data


tb_name = "UD_Naija-NSC"
train_path = os.path.join(root_path, tb_name, "pcm_nsc-ud-train.conllu")
test_path  = os.path.join(root_path, tb_name, "pcm_nsc-ud-test.conllu")
dev_path   = os.path.join(root_path, tb_name, "pcm_nsc-ud-dev.conllu")

train_sentences = load_conllu_sentences(train_path)
test_sentences  = load_conllu_sentences(test_path)
dev_sentences   = load_conllu_sentences(dev_path)

# Example
print(f"{len(train_sentences)} sentences loaded.")
print("Tokens:", train_sentences[0][0])
print("UPOS  :", train_sentences[0][1])


7279 sentences loaded.
Tokens: ['auntie', '<', 'good', 'morning', '//']
UPOS  : ['NOUN', 'PUNCT', 'ADJ', 'NOUN', 'PUNCT']


train_sentences[:10]

[(['auntie', '<', 'good', 'morning', '//'],
  ['NOUN', 'PUNCT', 'ADJ', 'NOUN', 'PUNCT']),
 (['good', 'morning', '!//'], ['ADJ', 'NOUN', 'PUNCT']),
 (['how', 'you', 'dey', 'now', '?//'],
  ['ADV', 'PRON', 'VERB', 'ADV', 'PUNCT']),
 (['i', 'dey', 'fine', '//'], ['PRON', 'VERB', 'ADJ', 'PUNCT']),
 (['how', 'your', 'night', '?//'], ['ADV', 'PRON', 'NOUN', 'PUNCT']),
 (['we', 'thank', 'god', '//'], ['PRON', 'VERB', 'PROPN', 'PUNCT']),
 (['hope', 'sey', '[', 'you', 'sleep', 'well', ']', '?//'],
  ['VERB', 'SCONJ', 'PUNCT', 'PRON', 'VERB', 'ADV', 'PUNCT', 'PUNCT']),
 (['ah', 'my', 'sister', '<', 'i', 'sleep', 'well', 'o', '!//'],
  ['INTJ', 'PRON', 'NOUN', 'PUNCT', 'PRON', 'VERB', 'ADV', 'PART', 'PUNCT']),
 (['una', 'get', 'light', 'for', 'una', 'area', 'last', 'night', '?//'],
  ['PRON', 'VERB', 'NOUN', 'ADP', 'PRON', 'NOUN', 'ADJ', 'NOUN', 'PUNCT']),
 (['we', 'no', 'get', 'o', '//'], ['PRON', 'AUX', 'VERB', 'PART', 'PUNCT'])]


print(f"Number of training examples: {len(train_sentences)}")
print(f"Number of test examples: {len(test_sentences)}")
print(f"Number of dev examples: {len(dev_sentences)}")

Number of training examples: 7279
Number of test examples: 972
Number of dev examples: 990
```

Tokenization

```
import random

# Set seed for reproducibility
random.seed(42)

train_subset = train_sentences #random.sample(train_sentences, int(0.2 * len(train_sentences)))
dev_subset   = dev_sentences #random.sample(dev_sentences,   int(0.2 * len(dev_sentences)))
test_subset  = test_sentences #random.sample(test_sentences,  int(0.2 * len(test_sentences)))


# Get full set of UPOS tags from training split
all_tags = sorted({tag for _, tags in train_subset for tag in tags})
tag2id = {tag: i for i, tag in enumerate(all_tags)}
id2tag = {i: tag for tag, i in tag2id.items()}


from transformers import AutoTokenizer

# Load a multilingual DistilBERT tokenizer
tokenizer = AutoTokenizer.from_pretrained("distilbert-base-multilingual-cased")

def tokenize_and_align(example, label_all_tokens=False):
    tokens, labels = example
    tokenized = tokenizer(tokens,
                          is_split_into_words=True,
                          truncation=True,
                          max_length=128)

    word_ids = tokenized.word_ids()
    aligned_labels = []
    previous_word_idx = None

    for word_idx in word_ids:
        if word_idx is None:
            aligned_labels.append(-100)
        elif word_idx != previous_word_idx:
            aligned_labels.append(tag2id[labels[word_idx]])
        else:
            aligned_labels.append(tag2id[labels[word_idx]] if label_all_tokens else -100)
        previous_word_idx = word_idx

    tokenized["labels"] = aligned_labels
    return tokenized
```

```
/usr/local/lib/python3.11/dist-packages/huggingface_hub/utils/_auth.py:94: UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab (https://huggingface.co/settings/t
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access public models or datasets.
  warnings.warn(
tokenizer_config.json: 100%  49.0/49.0 [00:00<00:00, 3.84kB/s]
config.json: 100%  466/466 [00:00<00:00, 35.3kB/s]
vocab.txt: 100%  996k/996k [00:00<00:00, 5.23MB/s]
tokenizer.json: 100%  1.96M/1.96M [00:00<00:00, 7.36MB/s]
```

```
from datasets import Dataset

# Wrap into HuggingFace Datasets
train_dataset = Dataset.from_list([{"tokens": t, "upos": u} for t, u in train_subset])
dev_dataset   = Dataset.from_list([{"tokens": t, "upos": u} for t, u in dev_subset])
test_dataset  = Dataset.from_list([{"tokens": t, "upos": u} for t, u in test_subset])

# Tokenize and align
train_tok = train_dataset.map(lambda ex: tokenize_and_align((ex["tokens"], ex["upos"])),
                              batched=False)
dev_tok   = dev_dataset.map(lambda ex: tokenize_and_align((ex["tokens"], ex["upos"])),
                            batched=False)
test_tok  = test_dataset.map(lambda ex: tokenize_and_align((ex["tokens"], ex["upos"])),
                             batched=False)
```

```
Map: 100%  7279/7279 [00:02<00:00, 3253.94 examples/s]
Map: 100%  990/990 [00:00<00:00, 1739.83 examples/s]
Map: 100%  972/972 [00:00<00:00, 1961.56 examples/s]
```

```
print("Original Tokens:", train_subset[0][0])
print("Tokenized Version:", tokenizer.convert_ids_to_tokens(train_tok[0]["input_ids"]))
print("Labels:", [id2tag[label] if label != -100 else -100 for label in train_tok[0]["labels"]])
```

```
Original Tokens: ['auntie', '<', 'good', 'morning', '//']
Tokenized Version: ['[CLS]', 'aun', '##tie', '<', 'good', 'morning', '/', '/', '[SEP]']
Labels: [-100, 'NOUN', -100, 'PUNCT', 'ADJ', 'NOUN', 'PUNCT', -100, -100]
```

Fine-tuning a Distilled Model (Baseline)

```
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from datasets import Dataset
import warnings
warnings.filterwarnings("ignore")


# 2) Load tokenizer & model
model_name = "distilbert-base-multilingual-cased"
tokenizer  = AutoTokenizer.from_pretrained(model_name)
model = AutoModelForTokenClassification.from_pretrained(
    model_name,
    num_labels=len(tag2id),
    id2label={i: t for t, i in tag2id.items()},
    label2id=tag2id,
)

# 3) Data collator to pad and align labels
data_collator = DataCollatorForTokenClassification(tokenizer)

# 4) Define metrics function (here: token accuracy)
def compute_metrics(p):
    preds = np.argmax(p.predictions, axis=2)
    labels = p.label_ids
    # only consider non -100 labels
```

```
    mask = labels != -100
    acc = (preds[mask] == labels[mask]).astype(np.float32).mean().item()
    return {"accuracy": acc}

# 5) Training arguments
training_args = TrainingArguments(
    output_dir="./baseline_distilbert",
    eval_strategy="epoch",      # skip eval for the fastest baseline
    save_strategy="no",            # skip checkpointing
    learning_rate=5e-5,
    per_device_train_batch_size=16,
    num_train_epochs=5,
    weight_decay=0.01,
    logging_steps=50,
)

# 6) Initialize Trainer
trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=train_tok,
    eval_dataset=dev_tok,
    tokenizer=tokenizer,
    data_collator=data_collator,
    compute_metrics=compute_metrics,
)

# 7) Train!
trainer.train()
```

```
model.safetensors: 100%                                  542M/542M [00:11<00:00, 64.3MB/s]
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
wandb: WARNING The `run_name` is currently set to the same value as `TrainingArguments.output_dir`. If this was n
wandb: Logging into wandb.ai. (Learn how to deploy a W&B server locally: https://wandb.me/wandb-server)
wandb: You can find your API key in your browser here: https://wandb.ai/authorize?ref=models
wandb: Paste an API key from your profile and hit enter: ·····
wandb: WARNING If you're specifying your api key in code, ensure this code is not shared publicly.
wandb: WARNING Consider setting the WANDB_API_KEY environment variable, or running `wandb login` from the command
wandb: No netrc file found, creating one.
wandb: Appending key for api.wandb.ai to your netrc file: /root/.netrc
wandb: Currently logged in as: johneze (john-eze) to https://api.wandb.ai. Use `wandb login --relogin` to force r
Tracking run with wandb version 0.20.1
Run data is saved locally in /content/wandb/run-20250707_080009-fjo3u04j
Syncing run ./baseline_distilbert to Weights & Biases (docs)
View project at https://wandb.ai/john-eze/huggingface
View run at https://wandb.ai/john-eze/huggingface/runs/fjo3u04j
[2275/2275 04:40, Epoch 5/5]
```

Epoch	Training Loss	Validation Loss	Accuracy
1	0.089300	0.082152	0.977695
2	0.061500	0.072785	0.980372
3	0.028400	0.074018	0.982294
4	0.016700	0.074990	0.981950
5	0.013100	0.080084	0.982431

```
TrainOutput(global_step=2275, training_loss=0.06768661073275975, metrics={'train_runtime': 388.309,
'train_samples_per_second': 93.727, 'train_steps_per_second': 5.859, 'total_flos': 541821045324384.0,
'train_loss': 0.06768661073275975, 'epoch': 5.0})
```

```
# Baseline evaluation on a small dev split
metrics = trainer.evaluate(eval_dataset=dev_tok)
print("Evaluation accuracy:", metrics["eval_accuracy"])
```

```
[124/124 00:01]
Evaluation accuracy: 0.9824308753013611
```

Task 2: Model Adjustment and Partial Freezing

Layer Freezing

```
from transformers import AutoModelForTokenClassification

def freeze_layers(model, freeze_strategy="first_k", k=2):
    """
    Freeze layers of a DistilBERT model based on the given strategy.

    Args:
        model: An instance of AutoModelForTokenClassification based on DistilBERT.
        freeze_strategy: Strategy to freeze layers. Options:
            - "all_encoder": Freeze all encoder layers.
            - "first_k": Freeze the first k encoder layers.
            - "last_k": Freeze the last k encoder layers.
            - "alternating": Freeze alternating layers (even-indexed).
        k: Number of layers to freeze for "first_k" or "last_k" strategies.
    """


    layers = model.distilbert.transformer.layer

    if freeze_strategy == "all_encoder":
        for layer in layers:
            for param in layer.parameters():
                param.requires_grad = False

    elif freeze_strategy == "first_k":
        for i, layer in enumerate(layers):
            if i < k:
                for param in layer.parameters():
                    param.requires_grad = False

    elif freeze_strategy == "alternating":
        for i, layer in enumerate(layers):
            if i % 2 == 0:
                for param in layer.parameters():
                    param.requires_grad = False
    else:
        raise ValueError(f"Unknown freeze_strategy: {freeze_strategy}")


model.distilbert.transformer.layer
```

```
ModuleList(
  (0-5): 6 x TransformerBlock(
    (attention): DistilBertSdpaAttention(
      (dropout): Dropout(p=0.1, inplace=False)
      (q_lin): Linear(in_features=768, out_features=768, bias=True)
      (k_lin): Linear(in_features=768, out_features=768, bias=True)
      (v_lin): Linear(in_features=768, out_features=768, bias=True)
      (out_lin): Linear(in_features=768, out_features=768, bias=True)
    )
```

```
        (sa_layer_norm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
        (ffn): FFN(
          (dropout): Dropout(p=0.1, inplace=False)
          (lin1): Linear(in_features=768, out_features=3072, bias=True)
          (lin2): Linear(in_features=3072, out_features=768, bias=True)
          (activation): GELUActivation()
        )
        (output_layer_norm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
      )
    )
```

```
len(model.distilbert.transformer.layer)
```

```
6
```

Freeze all encoder layers

```
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from datasets import Dataset
import warnings
warnings.filterwarnings("ignore")


# 2) Load tokenizer & model
model_name = "distilbert-base-multilingual-cased"
tokenizer  = AutoTokenizer.from_pretrained(model_name)
model = AutoModelForTokenClassification.from_pretrained(
    model_name,
    num_labels=len(tag2id),
    id2label={i: t for t, i in tag2id.items()},
    label2id=tag2id,
)

# 3) Apply partial-freeze
freeze_layers(model, freeze_strategy="all_encoder")

# 4) Prepare data collator
data_collator = DataCollatorForTokenClassification(tokenizer)

# 5) Metrics function
def compute_metrics(p):
    preds = np.argmax(p.predictions, axis=2)
    labels = p.label_ids
    mask = labels != -100
    acc = (preds[mask] == labels[mask]).astype(np.float32).mean().item()
    return {"accuracy": acc}

# 6) Training arguments
training_args = TrainingArguments(
    output_dir="./frozen_first_2_distilbert",
    eval_strategy="epoch",
    save_strategy="no",
    learning_rate=5e-5,
    per_device_train_batch_size=16,
    num_train_epochs=5,
    weight_decay=0.01,
```

```
    logging_steps=50,
)

# 7) Initialize Trainer with the already-frozen model
trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=train_tok,
    eval_dataset=dev_tok,             # now you can also evaluate each epoch
    tokenizer=tokenizer,
    data_collator=data_collator,
    compute_metrics=compute_metrics,
)

# 8) Train!
trainer.train()
```

```
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

[2275/2275 03:16, Epoch 5/5]

Epoch	Training Loss	Validation Loss	Accuracy
1	0.923000	0.789293	0.829662
2	0.463600	0.389504	0.904193
3	0.318700	0.289957	0.923890
4	0.273500	0.252709	0.930341
5	0.273400	0.242980	0.932263

```
TrainOutput(global_step=2275, training_loss=0.6158748027256556, metrics={'train_runtime': 196.1272,
'train_samples_per_second': 185.568, 'train_steps_per_second': 11.6, 'total_flos': 541821045324384.0,
'train_loss': 0.6158748027256556, 'epoch': 5.0})
```

```
# 8) Baseline evaluation on a small dev split
metrics = trainer.evaluate(eval_dataset=dev_tok)
print("Evaluation accuracy:", metrics["eval_accuracy"])
```

[124/124 00:01]

```
Evaluation accuracy: 0.9322627186775208
```

Freeze first 2 layers

```
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from datasets import Dataset
import warnings
warnings.filterwarnings("ignore")


# 2) Load tokenizer & model
model_name = "distilbert-base-multilingual-cased"
tokenizer  = AutoTokenizer.from_pretrained(model_name)
model = AutoModelForTokenClassification.from_pretrained(
```

```
    model_name,
    num_labels=len(tag2id),
    id2label={i: t for t, i in tag2id.items()},
    label2id=tag2id,
)

# 3) Apply partial-freeze
freeze_layers(model, freeze_strategy="first_k", k=2)

# 4) Prepare data collator
data_collator = DataCollatorForTokenClassification(tokenizer)

# 5) Metrics function
def compute_metrics(p):
    preds = np.argmax(p.predictions, axis=2)
    labels = p.label_ids
    mask = labels != -100
    acc = (preds[mask] == labels[mask]).astype(np.float32).mean().item()
    return {"accuracy": acc}

# 6) Training arguments
training_args = TrainingArguments(
    output_dir="./frozen_first_2_distilbert",
    eval_strategy="epoch",
    save_strategy="no",
    learning_rate=5e-5,
    per_device_train_batch_size=16,
    num_train_epochs=5,
    weight_decay=0.01,
    logging_steps=50,
)

# 7) Initialize Trainer with the already-frozen model
trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=train_tok,
    eval_dataset=dev_tok,             # now you can also evaluate each epoch
    tokenizer=tokenizer,
    data_collator=data_collator,
    compute_metrics=compute_metrics,
)

# 8) Train!
trainer.train()
```

```
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```


[2275/2275 04:09, Epoch 5/5]

Epoch	Training Loss	Validation Loss	Accuracy
1	0.097600	0.090729	0.974950
2	0.068800	0.078094	0.978656
3	0.037300	0.083517	0.978931
4	0.021000	0.080185	0.980646
5	0.017000	0.082884	0.981264

```
TrainOutput(global_step=2275, training_loss=0.07960525478635515, metrics={'train_runtime': 249.6293,
'train_samples_per_second': 145.796, 'train_steps_per_second': 9.114, 'total_flos': 541821045324384.0,
'train_loss': 0.07960525478635515, 'epoch': 5.0})
```

```
# 8) Baseline evaluation on a small dev split
metrics = trainer.evaluate(eval_dataset=dev_tok)
print("Evaluation accuracy:", metrics["eval_accuracy"])
```

```
[124/124 00:02]
Evaluation accuracy: 0.9812641739845276
```

Freeze first 4 layers

```
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from datasets import Dataset
import warnings
warnings.filterwarnings("ignore")


# 2) Load tokenizer & model
model_name = "distilbert-base-multilingual-cased"
tokenizer  = AutoTokenizer.from_pretrained(model_name)
model = AutoModelForTokenClassification.from_pretrained(
    model_name,
    num_labels=len(tag2id),
    id2label={i: t for t, i in tag2id.items()},
    label2id=tag2id,
)

# 3) Apply partial-freeze
freeze_layers(model, freeze_strategy="first_k", k=4)

# 4) Prepare data collator
data_collator = DataCollatorForTokenClassification(tokenizer)

# 5) Metrics function
def compute_metrics(p):
    preds = np.argmax(p.predictions, axis=2)
    labels = p.label_ids
    mask = labels != -100
    acc = (preds[mask] == labels[mask]).astype(np.float32).mean().item()
    return {"accuracy": acc}

# 6) Training arguments
training_args = TrainingArguments(
    output_dir="./frozen_first_4_distilbert",
    eval_strategy="epoch",
    save_strategy="no",
    learning_rate=5e-5,
    per_device_train_batch_size=16,
    num_train_epochs=5,
    weight_decay=0.01,
    logging_steps=50,
)

# 7) Initialize Trainer with the already-frozen model
trainer = Trainer(
    model=model,
```

```
    args=training_args,
    train_dataset=train_tok,
    eval_dataset=dev_tok,             # now you can also evaluate each epoch
    tokenizer=tokenizer,
    data_collator=data_collator,
    compute_metrics=compute_metrics,
)

# 8) Train!
trainer.train()
```

```
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

[2275/2275 03:43, Epoch 5/5]

Epoch	Training Loss	Validation Loss	Accuracy
1	0.130700	0.113666	0.966372
2	0.091700	0.091639	0.973578
3	0.056500	0.090377	0.975225
4	0.039900	0.089033	0.976117
5	0.036200	0.087311	0.977078

```
TrainOutput(global_step=2275, training_loss=0.11099234070096697, metrics={'train_runtime': 223.5484,
'train_samples_per_second': 162.806, 'train_steps_per_second': 10.177, 'total_flos': 541821045324384.0,
'train_loss': 0.11099234070096697, 'epoch': 5.0})
```

```
# Baseline evaluation on a small dev split
dev_hf = dev_tok
metrics = trainer.evaluate(eval_dataset=dev_hf)
print("Evaluation accuracy:", metrics["eval_accuracy"])
```

[124/124 00:01]

```
Evaluation accuracy: 0.9770777821540833
```

Alternate freezing strategy

```
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from datasets import Dataset
import warnings
warnings.filterwarnings("ignore")


# Load tokenizer & model
model_name = "distilbert-base-multilingual-cased"
tokenizer  = AutoTokenizer.from_pretrained(model_name)
model = AutoModelForTokenClassification.from_pretrained(
    model_name,
    num_labels=len(tag2id),
    id2label={i: t for t, i in tag2id.items()},
    label2id=tag2id,
)
```

```
# Apply partial-freeze
freeze_layers(model, freeze_strategy="alternating")

# Prepare data collator
data_collator = DataCollatorForTokenClassification(tokenizer)

# Metrics function
def compute_metrics(p):
    preds = np.argmax(p.predictions, axis=2)
    labels = p.label_ids
    mask = labels != -100
    acc = (preds[mask] == labels[mask]).astype(np.float32).mean().item()
    return {"accuracy": acc}

# Training arguments
training_args = TrainingArguments(
    output_dir="./frozen_alt_distilbert",
    eval_strategy="epoch",
    save_strategy="no",
    learning_rate=5e-5,
    per_device_train_batch_size=16,
    num_train_epochs=5,
    weight_decay=0.01,
    logging_steps=50,
)

# Initialize Trainer with the already-frozen model
trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=train_tok,
    eval_dataset=dev_tok,
    tokenizer=tokenizer,
    data_collator=data_collator,
    compute_metrics=compute_metrics,
)

# Train
trainer.train()
```

```
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

Epoch	Training Loss	Validation Loss	Accuracy
1	0.100300	0.090939	0.973989
2	0.071100	0.074628	0.978794
3	0.038700	0.076613	0.979754
4	0.027100	0.076771	0.980784
5	0.022800	0.078143	0.982294

```
TrainOutput(global_step=2275, training_loss=0.08658811562663907, metrics={'train_runtime': 236.4821,
'train_samples_per_second': 153.902, 'train_steps_per_second': 9.62, 'total_flos': 541821045324384.0,
'train_loss': 0.08658811562663907, 'epoch': 5.0})
```

```
# 8) Baseline evaluation on a small dev split
dev_hf = dev_tok
metrics = trainer.evaluate(eval_dataset=dev_hf)
print("Evaluation accuracy:", metrics["eval_accuracy"])
```

```
[124/124 00:01]
Evaluation accuracy: 0.9822936058044434
```

Task 3: Analysis and Comparison

Analysis of Parameters

```
import torch
from transformers import AutoModelForTokenClassification
import pandas as pd

# Define freeze function
def freeze_layers(model, strategy, k=0):
    # Unfreeze all first
    for param in model.parameters():
        param.requires_grad = True
    layers = model.distilbert.transformer.layer
    if strategy == "all_encoder":
        for layer in layers:
            for param in layer.parameters():
                param.requires_grad = False
    elif strategy == "first_k":
        for i, layer in enumerate(layers):
            if i < k:
                for param in layer.parameters():
                    param.requires_grad = False
    elif strategy == "alternating":
        for i, layer in enumerate(layers):
            if i % 2 == 0:
                for param in layer.parameters():
                    param.requires_grad = False

# Load base model name
model_name = "distilbert-base-multilingual-cased"
strategies = [
    ("No Freeze", None, 0),
    ("Freeze All", "all_encoder", 0),
    ("Freeze First 2", "first_k", 2),
    ("Freeze First 4", "first_k", 4),
    ("Alternating Freeze", "alternating", 0),
]

results = []

for name, strat, k in strategies:
    model = AutoModelForTokenClassification.from_pretrained(
        model_name, num_labels=10  # dummy num_labels
    )
    if strat:
        freeze_layers(model, strat, k)
    total_params = sum(p.numel() for p in model.parameters())
    trainable_params = sum(p.numel() for p in model.parameters() if p.requires_grad)
    results.append({
        "Strategy": name,
        "Total Params": total_params,
        "Trainable Params": trainable_params,
        "Trainable (%)": trainable_params / total_params * 100
    })

df_params = pd.DataFrame(results)
```

```
# Display the DataFrame to the user
display(df_params)
```

```
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
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Some weights of DistilBertForTokenClassification were not initialized from the model checkpoint at distilbert-bas
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

	Strategy	Total Params	Trainable Params	Trainable (%)
0	No Freeze	134741770	134741770	100.000000
1	Freeze All	134741770	92214538	68.437974
2	Freeze First 2	134741770	120566026	89.479325
3	Freeze First 4	134741770	106390282	78.958650
4	Alternating Freeze	134741770	113478154	84.218987

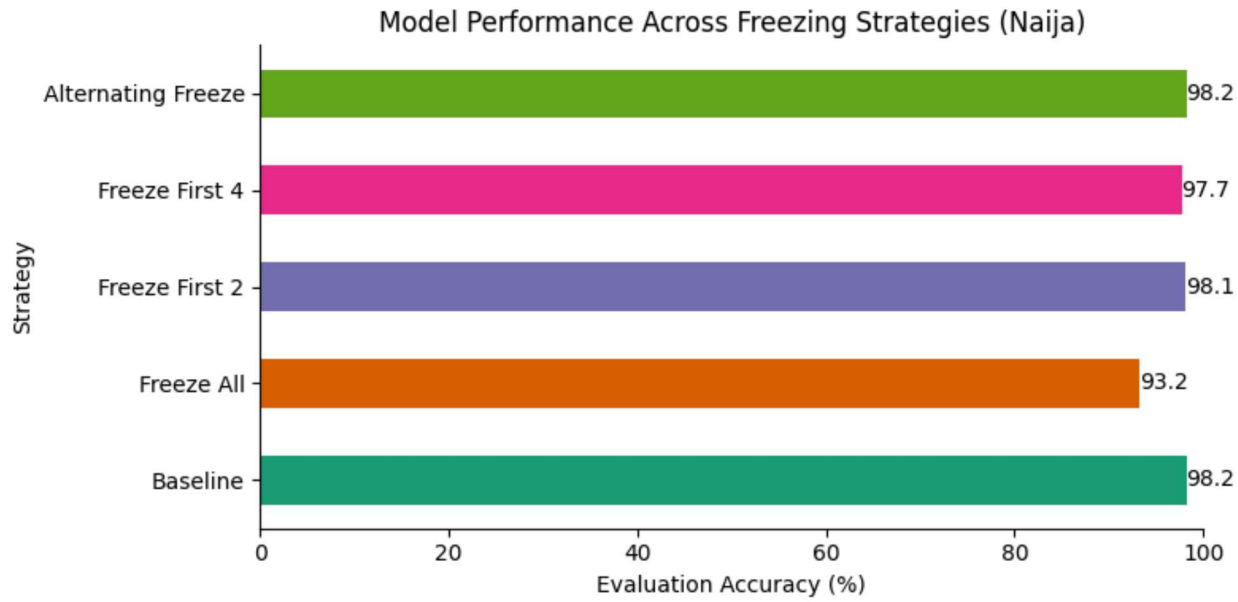
Next steps: Generate code with df_params | View recommended plots | New interactive sheet

Model Performance Across Freezing Strategies

```
from matplotlib import pyplot as plt
import seaborn as sns
import pandas as pd

# Example results - replace with your actual evaluation metrics
data = {
    "Strategy": ["Baseline", "Freeze All", "Freeze First 2", "Freeze First 4", "Alternating Freeze"],
    "Dev Accuracy": [98.2, 93.2, 98.1, 97.7, 98.2]
}
df_results = pd.DataFrame(data)

# Display the DataFrame to the user
display(df_results)

# Create horizontal bar chart with Dark2 palette
palette = sns.color_palette("Dark2", n_colors=len(df_results))
plt.figure(figsize=(8, 4))
ax = df_results.set_index('Strategy')['Dev Accuracy'].plot(
    kind='barh',
    color=palette
)

# Annotate each bar with its accuracy value
for i, (strategy, accuracy) in enumerate(zip(df_results['Strategy'], df_results['Dev Accuracy'])):
    ax.text(accuracy + 0.005, i, f"{accuracy:.1f}", va='center')

# Remove top and right spines
ax.spines['top'].set_visible(False)
ax.spines['right'].set_visible(False)

plt.xlabel("Evaluation Accuracy (%)")
plt.title("Model Performance Across Freezing Strategies (Naija)")
plt.xlim(0, 100.0)  # ensure space for labels on the right
```

```
plt.tight_layout()
plt.show()
```

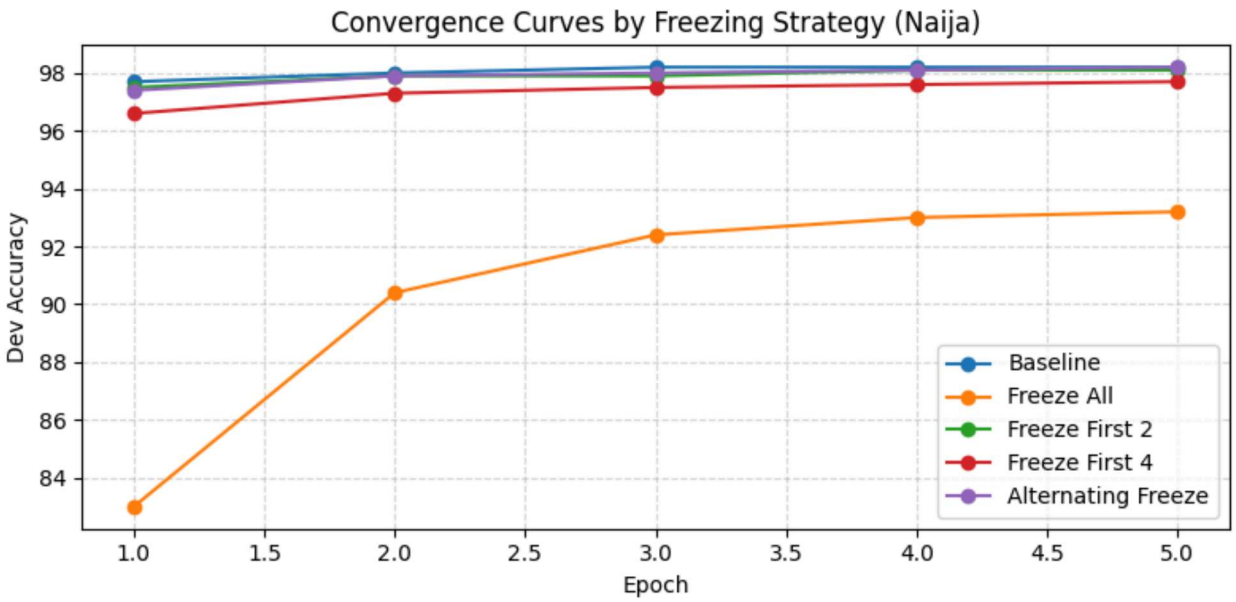
	Strategy	Dev Accuracy
0	Baseline	98.2
1	Freeze All	93.2
2	Freeze First 2	98.1
3	Freeze First 4	97.7
4	Alternating Freeze	98.2



Next steps: Generate code with df_results | View recommended plots | New interactive sheet

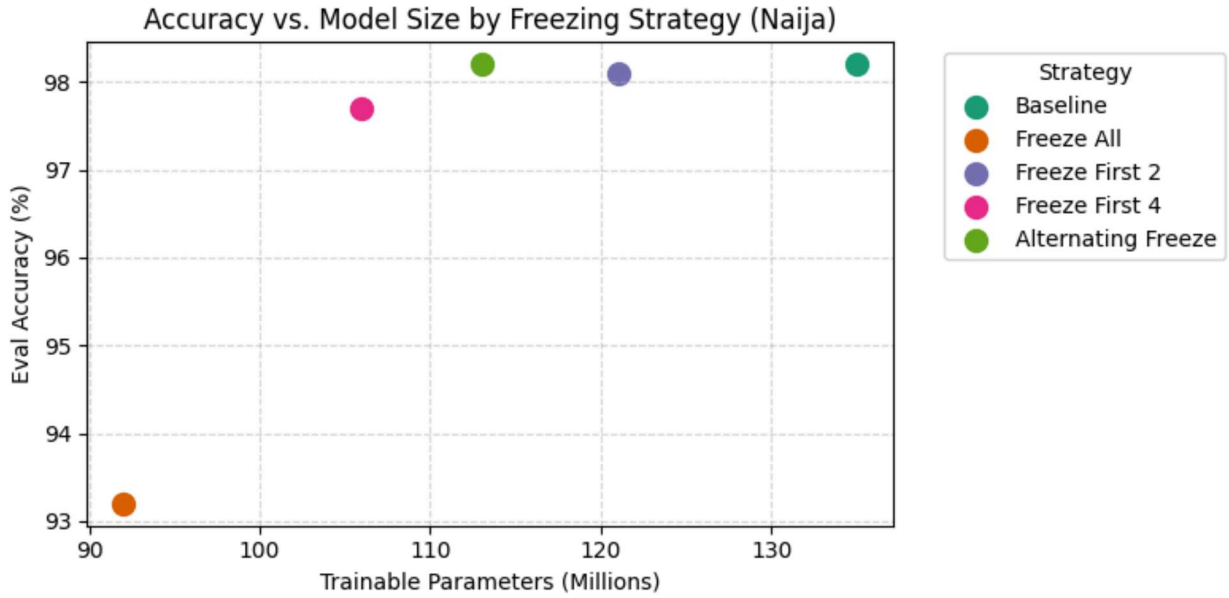
Epoch Convergence Curve

```
import matplotlib.pyplot as plt

# Example: histories is a dict mapping strategy → list of accuracies per epoch
histories = {
    "Baseline":           [97.7, 98.0, 98.2, 98.2, 98.2],
    "Freeze All":         [83.0, 90.4, 92.4, 93.0, 93.2],
    "Freeze First 2":     [97.5, 97.9, 97.9, 98.1, 98.1],
    "Freeze First 4":     [96.6, 97.3, 97.5, 97.6, 97.7],
    "Alternating Freeze": [97.4, 97.9, 98.0, 98.1, 98.2],
}

plt.figure(figsize=(8,4))
for strat, accs in histories.items():
    plt.plot(range(1, len(accs)+1), accs, marker='o', label=strat)
plt.xlabel("Epoch")
plt.ylabel("Dev Accuracy")
plt.title("Convergence Curves by Freezing Strategy (Naija)")
plt.legend()
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```



Accuracy vs Model Size Trade-off

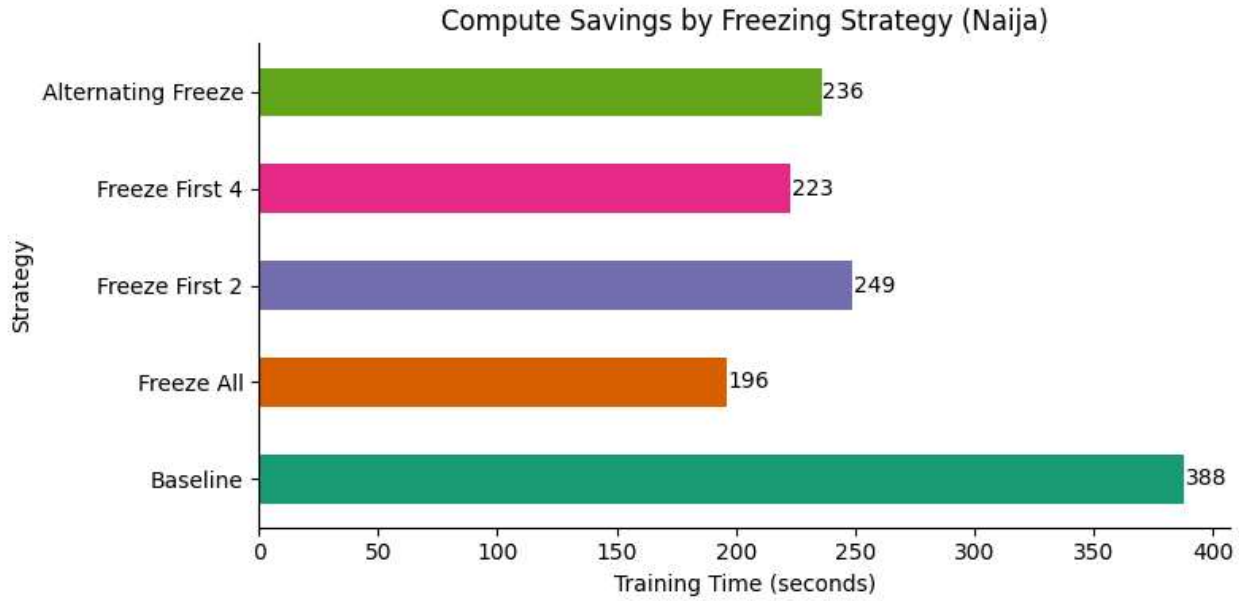
```
import matplotlib.pyplot as plt
import seaborn as sns

# Example data — replace with your actual numbers
param_counts = {
    "Baseline":           135,
    "Freeze All":          92,
    "Freeze First 2":      121,
    "Freeze First 4":      106,
    "Alternating Freeze":  113,
}
accuracies = {
    "Baseline":           98.2,
    "Freeze All":          93.2,
    "Freeze First 2":     98.1,
    "Freeze First 4":     97.7,
    "Alternating Freeze": 98.2,
}

# Create a consistent color palette
palette = sns.color_palette("Dark2", n_colors=len(param_counts))

plt.figure(figsize=(8, 4))
for (strategy, count), color in zip(param_counts.items(), palette):
    plt.scatter(count, accuracies[strategy], s=100, color=color, label=strategy)

plt.xlabel("Trainable Parameters (Millions)")
plt.ylabel("Eval Accuracy (%)")
plt.title("Accuracy vs. Model Size by Freezing Strategy (Naija)")
plt.grid(True, linestyle='--', alpha=0.5)

# Add legend instead of inline labels
plt.legend(title="Strategy", bbox_to_anchor=(1.05, 1), loc='upper left')

plt.tight_layout()
plt.show()
```



Training Time Saving

```
from matplotlib import pyplot as plt
import seaborn as sns
import pandas as pd

# Example training times - replace with your actual timing metrics
data = {
    "Strategy": ["Baseline", "Freeze All", "Freeze First 2", "Freeze First 4", "Alternating Freeze"],
    "Training Time (seconds)": [388, 196, 249, 223, 236]
}
df_times = pd.DataFrame(data)

# Display the DataFrame to the user
display(df_times)

# Create horizontal bar chart with Dark2 palette
palette = sns.color_palette("Dark2", n_colors=len(df_times))
plt.figure(figsize=(8, 4))
ax = df_times.set_index('Strategy')['Training Time (seconds)'].plot(
    kind='barh',
    color=palette
)

# Annotate each bar with its training time value
for i, (strategy, time_val) in enumerate(zip(df_times['Strategy'], df_times['Training Time (seconds)'])):
    ax.text(time_val + 0.5, i, f"{time_val:.0f}", va='center')

# Remove top and right spines
ax.spines['top'].set_visible(False)
ax.spines['right'].set_visible(False)

plt.xlabel("Training Time (seconds)")
plt.title("Compute Savings by Freezing Strategy (Naija)")
plt.tight_layout()
plt.show()
```

	Strategy	Training Time (seconds)
0	Baseline	388
1	Freeze All	196
2	Freeze First 2	249
3	Freeze First 4	223
4	Alternating Freeze	236



Next steps: Generate code with df_times | View recommended plots | New interactive sheet

Result Summary

```
import pandas as pd

# 1) Raw experiment metrics
data = {
    "Strategy": [
        "Baseline",
        "Freeze All",
        "Freeze First 2",
        "Freeze First 4",
        "Alternating Freeze"
    ],
    "Dev Accuracy (%)": [
        98.2,  # Baseline
        93.2,  # Freeze All
        98.1,  # Freeze First 2
        97.7,  # Freeze First 4
        98.2   # Alternating Freeze
    ],
    "Trainable Params (M)": [
        134,  # Baseline
        92,   # Freeze All
        120,  # Freeze First 2
        106,  # Freeze First 4
        113   # Alternating Freeze
    ],
    "Training Time (s)": [
```

```
        388,  # Baseline
        196,  # Freeze All
        249,  # Freeze First 2
        223,  # Freeze First 4
        236   # Alternating Freeze
    ]
}

# 2) Build DataFrame
df = pd.DataFrame(data)

# 3) Compute savings (%) relative to baseline time
baseline_time = df.loc[df["Strategy"] == "Baseline", "Training Time (s)"].iloc[0]
df["Compute Savings (%)"] = (
    (baseline_time - df["Training Time (s)"]) / baseline_time * 100
).round(1)

# 4) Rearrange columns for readability
df = df[[
    "Strategy",
    "Dev Accuracy (%)",
    "Trainable Params (M)",
    "Training Time (s)",
    "Compute Savings (%)"
]]

# 5) Display as markdown table (or use display(df) in a notebook)
print(df.to_markdown(index=False))
```

Strategy	Dev Accuracy (%)	Trainable Params (M)	Training Time (s)	Compute Savings (%)
Baseline	98.2	134	388	0
Freeze All	93.2	92	196	49.5
Freeze First 2	98.1	120	249	35.8
Freeze First 4	97.7	106	223	42.5
Alternating Freeze	98.2	113	236	39.2