```
import pandas as pd
import numpy as np
from collections import defaultdict, Counter
from datasets import load_dataset, Dataset as HFDataset
from sklearn.metrics import accuracy_score
import warnings
import string
import os
import shutil
import torch
import re
import random
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
import sentencepiece
import evaluate
from sacrebleu import BLEU
from transformers import AutoTokenizer, AutoModelForSeq2SeqLM, Seq2SeqTrainingArguments, Seq2SeqTrainer, pipeline, EvalPrediction, Traine
import sys
import tensorflow as tf
```

Data Preprocessing

Load The Data

```
dataset = load_dataset("    ")
print(dataset.keys())
```

```
dict_keys(['train', 'test'])
```

```
print(dataset['train'].column_names)
print(dataset['train'][0])
```

```
['index', 'Text', 'label']
{'index': 2835, 'Text': 'ل ماذا؟ مثل لا شيء، مثل ذاته ليس غير.. لو قدر لنبعة الماء أن تحس، إذن لأحسَّت ذلك الشعور، العطاء المحض الذي يخلق من جديد كلما شرب عابر من مائها
```

```
df = dataset['train'].to_pandas()
df.shape
```

```
(2380, 3)
```

Clean and Normalize Words

```
def normalize_arabic(text):
    text = re.sub("[إأآا]", "ا", text)
    text = re.sub("ى", "ي", text)
    text = re.sub("ؤ", "ء", text)
    text = re.sub("ئ", "ء", text)
    text = re.sub("ة", "ه", text)
    text = re.sub("گ", "ك", text)
    text = re.sub(" و ", " ", text)
    return text


# Define Arabic diacritics
arabic_diacritics = re.compile(r"""
    ّ    | # Shadda
    َ    | # Fatha
    ً    | # Tanwin Fath
    ُ    | # Damma
    ٌ    | # Tanwin Damm
    ِ    | # Kasra
    ٍ    | # Tanwin Kasr
    ْ    | # Sukun
     -      # Tatweel
""", re.VERBOSE)

def remove_diacritics(text):
    text = re.sub(arabic_diacritics, '', text)
    return text

def remove_non_arabic_and_numbers(text):
    # Keep only Arabic characters and spaces
    arabic_pattern = re.compile(r'[^\u0600-\u06FF\u0750-\u077F\u08A0-\u08FF\uFB50-\uFDFF\uFE70-\uFEFF\s]')
    return arabic_pattern.sub('', text)

# Define punctuation characters
arabic_punctuations = '''`÷×ـ–“…”!|+¦~{}',.؟":/،ـ][%^&*()_<>؛'''
english_punctuations = string.punctuation
punctuations = arabic_punctuations + english_punctuations

def remove_punctuations(text):
    translator = str.maketrans('', '', punctuations)
    return text.translate(translator)


def normalize_arabic_text(text):
    text = normalize_arabic(text)
    text = remove_diacritics(text)
    text = remove_non_arabic_and_numbers(text)
    text = remove_punctuations(text)
    return text



# Extract all text from the 'Text' column
text = ' '.join(df["Text"])
text = normalize_arabic_text(text)
words = text.split()
vocab = list(set(words))
print(len(vocab))
```

```
72804
```

Generate Synthetic Training Data

Insertion

```
def insert(word, max_typos=2):
    arabic_letters = 'ابتثجحخدذرزسشصضطظعغفقكلمنهوي'
    possible_words = set()
    for _ in range(max_typos):
        pos = random.randint(0, len(word))
        letter = random.choice(arabic_letters)
        new_word = word[:pos] + letter + word[pos:]
        possible_words.add(new_word)
    return possible_words
```

Deletion

```
def delete(word):
    if len(word) < 2:
        return set()
    pos = random.randint(0, len(word)-1)
    return {word[:pos] + word[pos+1:]}
```

Replacing

```
def replace(word):
    arabic_letters = 'ابتثجحخدذرزسشصضطظعغفقكلمنهوي'
    if len(word) < 1:
        return set()
    pos = random.randint(0, len(word)-1)
    letter = random.choice(arabic_letters)
    return {word[:pos] + letter + word[pos+1:]}
```

Switching

```
def switch(word):
    if len(word) < 2:
        return set()
    pos = random.randint(0, len(word)-2)
    new_word = word[:pos] + word[pos+1] + word[pos] + word[pos+2:]
    return {new_word}
```

```
def add_arabic_typo(word, max_total_typos=3):
    if len(word) < 2:
        return [word]

    common_typos = {
        'ا': ['أ', 'إ', 'آ', ''],
        'أ': ['ا', 'إ', 'ء'],
        'ة': ['ه', 'ت'],
        'ه': ['ة', 'ح'],
        'ي': ['ى', 'ئ'],
        'و': ['ؤ', 'ء', ''],
        'ن': ['ت', 'ب'],
        'ت': ['ث', 'ن'],
        'س': ['ش', 'ص'],
    }

    typo_ops = [insert, delete, replace, switch]
    typo_variants = set()


    for _ in range(2):
        pos = random.randint(0, len(word)-1)
        char = word[pos]
        if char in common_typos:
            replacement = random.choice(common_typos[char])
            typo = word[:pos] + replacement + word[pos+1:]
            typo_variants.add(typo)


    while len(typo_variants) < max_total_typos:
        op = random.choice(typo_ops)
        typo_variants.update(op(word))

    return list(typo_variants)
```

Create Training Pairs

```
synthetic_data = []

for word in vocab [:10000]:
    typo_variants = add_arabic_typo(word)
    for incorrect in typo_variants:
        if incorrect != word:
            synthetic_data.append({'inputs': incorrect.strip(), 'targets': word.strip()})

df = pd.DataFrame(synthetic_data)

df.to_csv("autocorrect_dataset.csv", index=False)



with open("autocorrect_dataset.csv", encoding="utf-8") as f:
    for i in range(10):
        print(f.readline())
```

```
inputs,targets

الاسررار,الاسرار

إلاسرار,الاسرار

الاسار,الاسرار

الاسرارك,الاسرار

بومركبه,ومركبه

مركبه,ومركبه

زومركبه,ومركبه

بأتوا,باتوا

باتوإ,باتوا
```

```
df.shape
```

```
(31851, 2)
```

Data Cleaning

```
def clean_dataset(df):

    df = df.dropna(subset=["inputs", "targets"])

    df = df[df["inputs"].apply(lambda x: isinstance(x, str))]
    df = df[df["targets"].apply(lambda x: isinstance(x, str))]

    df = df.reset_index(drop=True)

    return df
```

Data Spliting

```
# Load and clean dataset
df = pd.read_csv("autocorrect_dataset.csv")
df = clean_dataset(df)

# Train/validation split
train_df, val_df = train_test_split(df, test_size=0.1, random_state=42)
train_dataset = HFDataset.from_pandas(train_df)
val_dataset = HFDataset.from_pandas(val_df)
```

```
df.shape
```

```
(31851, 2)
```

Check Duplicated Values

```
duplicates = train_df[train_df['inputs'] == train_df['targets']]
print(f"Found {len(duplicates)} identical input-output pairs")
```

```
Found 0 identical input-output pairs
```

Model Fine-Tuning

Load Tokenizer & Model

```
tokenizer = AutoTokenizer.from_pretrained("CAMeL-Lab/arat5-coda", legacy=False)
model = AutoModelForSeq2SeqLM.from_pretrained("CAMeL-Lab/arat5-coda")

def tokenize(batch):
    input_encodings = tokenizer(batch['inputs'], padding="max_length", truncation=True, max_length=128)
    target_encodings = tokenizer(batch['targets'], padding="max_length", truncation=True, max_length=128)

    labels = target_encodings["input_ids"]
    labels = [
        [(l if l != tokenizer.pad_token_id else -100) for l in label]
        for label in labels
    ]

    return {
        "input_ids": input_encodings["input_ids"],
        "attention_mask": input_encodings["attention_mask"],
        "labels": labels
    }
```

```
# Apply tokenization
train_dataset = train_dataset.map(tokenize, batched=True, remove_columns=["inputs", "targets"])
val_dataset = val_dataset.map(tokenize, batched=True, remove_columns=["inputs", "targets"])
```

```
Map: 100%|██████████| 28665/28665 [00:16<00:00, 1705.89 examples/s]
Map: 100%|██████████| 3186/3186 [00:01<00:00, 1660.88 examples/s]
```

Model Training Setup

```
class LossTrackerCallback(TrainerCallback):
    def __init__(self):
        self.eval_losses = []
        self.train_losses = []

    def on_evaluate(self, args, state, control, metrics, **kwargs):
        if "eval_loss" in metrics:
            self.eval_losses.append((state.global_step, metrics["eval_loss"]))

    def on_log(self, args, state, control, logs=None, **kwargs):
        if logs and "loss" in logs:
            self.train_losses.append((state.global_step, logs["loss"]))



training_args = Seq2SeqTrainingArguments(

      output_dir="./results",
      per_device_train_batch_size=16,
      per_device_eval_batch_size=16,
      warmup_steps=200,
      warmup_ratio=0.1,
      weight_decay=0.01,
      gradient_accumulation_steps=1,
      learning_rate=2e-5,
      fp16=True,
      logging_dir="./logs",
      logging_steps=500,
      predict_with_generate=True,
      generation_max_length=16,
      gradient_checkpointing=True,
      max_grad_norm=1.0,
      lr_scheduler_type="cosine",
      optim="adafactor",
      report_to="tensorboard"
      )

loss_tracker = LossTrackerCallback()

# Trainer
trainer = Seq2SeqTrainer(
    model=model,
    args=training_args,
    train_dataset=train_dataset,
    eval_dataset=val_dataset,
    tokenizer=tokenizer,
    compute_metrics=compute_metrics,
    callbacks=[loss_tracker]
)
```

Model Training

Train The Model

```
num_epochs = 2

for epoch in range(num_epochs):
    print(f"\nEpoch {epoch + 1}/{num_epochs}")
    trainer.train()
    eval_results = trainer.evaluate()
    print(f"Validation Loss: {eval_results['eval_loss']:.4f}")
```

```
Epoch 1/2
`use_cache=True` is incompatible with gradient checkpointing. Setting `use_cache=False`...
[5376/5376 13:51:36, Epoch 3/3]

Step  Training Loss
 500      3.896200
1000      2.641700
1500      2.358500
2000      2.220500
2500      2.088500
3000      2.054900
3500      2.009200
4000      1.913900
4500      1.923300
5000      1.894700

Passing a tuple of `past_key_values` is deprecated and will be removed in Transformers v4.48.0. You should pass an instance of `Enc
[200/200 10:52:16]
Metric computation error: name 'bleu_scorer' is not defined
Validation Loss: 1.5322

Epoch 2/2
[5376/5376 10:38:22, Epoch 3/3]

Step  Training Loss
 500      1.913600
1000      1.863400
1500      1.792000
2000      1.737900
2500      1.659600
3000      1.646200
3500      1.649300
4000      1.556200
4500      1.583800
5000      1.555700

Metric computation error: name 'bleu_scorer' is not defined
Validation Loss: 1.3276
```

Evaluation

```python
from datasets import load_dataset
from transformers import AutoTokenizer, AutoModelForSequenceClassification
import torch
import evaluate

label_names = list(set(dataset["train"]["label"]))
label2id = {label: i for i, label in enumerate(label_names)}
id2label = {i: label for label, i in label2id.items()}

# Load tokenizer and model
model_path = "D:\\NLP_model\\my_model"
tokenizer = AutoTokenizer.from_pretrained(model_path)
model = AutoModelForSequenceClassification.from_pretrained(model_path)

# Load metric
metric = evaluate.load("accuracy")

# Evaluation loop
total_samples = 100
predictions = []
references = []

for example in dataset["test"].select(range(total_samples)):
    text = example["Text"]
    true_label = label2id[example["label"]]  # convert to integer
    inputs = tokenizer(text, return_tensors="pt", truncation=True, padding=True)
    with torch.no_grad():
        outputs = model(**inputs)
        pred_id = torch.argmax(outputs.logits, dim=1).item()

    predictions.append(pred_id)
    references.append(true_label)

# Compute accuracy
results = metric.compute(predictions=predictions, references=references)
print(f"\n Accuracy on {total_samples} test samples: {results['accuracy']:.2f}")
```

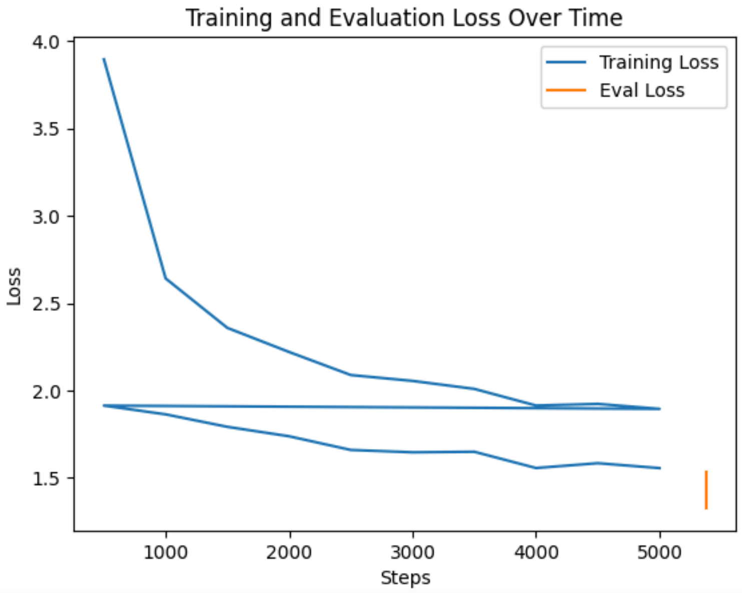
```
Some weights of T5ForSequenceClassification were not initialized from the model checkpoint at D:\NLP_model\my_model and are newly ir
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.

 Accuracy on 100 test samples: 0.05
```

```
# Plot training loss
steps, train_losses = zip(*loss_tracker.train_losses)
plt.plot(steps, train_losses, label="Training Loss")

# Plot evaluation loss
if loss_tracker.eval_losses:
    eval_steps, eval_losses = zip(*loss_tracker.eval_losses)
    plt.plot(eval_steps, eval_losses, label="Eval Loss")

plt.xlabel("Steps")
plt.ylabel("Loss")
plt.legend()
plt.title("Training and Evaluation Loss Over Time")
plt.show()
```



GUI

```
import tkinter as tk
from tkinter import ttk
from transformers import AutoTokenizer, AutoModelForSeq2SeqLM
import torch


# Function to perform correction
def correct_text():
    input_text = input_box.get("1.0", tk.END).strip()
    if not input_text:
        output_label.config(text="يرجى إدخال نص")
        return

    inputs = tokenizer(input_text, return_tensors="pt", padding=True, truncation=True)
    with torch.no_grad():
        outputs = model.generate(**inputs, max_new_tokens=128)
    corrected = tokenizer.decode(outputs[0], skip_special_tokens=True)
    output_label.config(text=corrected)

# Create GUI window
root = tk.Tk()
root.title("مصحح اللغة العربية")
root.geometry("600x400")
root.configure(bg="#1e1e2f")

# Title
title = tk.Label(root, text="تصحيح النصوص العربية", font=("Segoe UI", 20), bg="#1e1e2f", fg="#ffffff")
title.pack(pady=10)

# Input Text Box
input_box = tk.Text(root, font=("Segoe UI", 14), height=6, wrap=tk.WORD, bg="#2c2c3c", fg="#ffffff", insertbackground="white", padx=10,
input_box.pack(padx=20, pady=10, fill=tk.BOTH)

# Correct Button
correct_button = ttk.Button(root, text="تصحيح", command=correct_text)
style = ttk.Style()
style.theme_use("clam")
style.configure("TButton", font=("Segoe UI", 12), foreground="white", background="#3a86ff", padding=10)
style.map("TButton", background=[("active", "#265df2")])
correct_button.pack(pady=10)

# Output Label
output_label = tk.Label(root, text="", font=("Segoe UI", 14), wraplength=560, justify="right", bg="#1e1e2f", fg="#00ffb3")
output_label.pack(padx=20, pady=10)

root.mainloop()
```