CS6700FinalProject

April 15, 2025

1 Extreme Model Distillation

This notebook aims to understand how well large language model predictions of multiple classes can be approximated by much smaller models. We explore this using Random Forest, KNN, Decoder-Only Transformer, and an RNN model.

The data was collected by asking Llama 3.3:8b for 10,000 descriptions of foods. It was then asked to predict the main ingredient, sweetener, fat or oil, seasoning, allergens, contains allergen. That data was used to train the models in this notebook to determine the performance of the KNN and Random Forest models to predict whether or not it contains an allergen based on the main_ingredient, sweetner, fat or oil, and seasoning factors. The Decoder-Only Transformer and RNN models use the tokens created from the food description to predict whether or not an allergen is present

We train a Decoder-Only Transformer and RNN model to learn patterns from food descriptions and associated data stored in a CSV file. The notebook performs the following steps:

1. **Imports & Setup:** Imports necessary libraries and checks for the availability of `torch` and `tokenizers`.
2. **Data Creation:** Creates a placeholder `food_predictions.csv` if it doesn't exist, allowing the notebook to run initially.
3. **Tokenizer:** Defines and trains a Byte-Pair Encoding (BPE) tokenizer on the input text data.
4. **Dataset:** Defines a custom dataset class to load, preprocess, and tokenize the data from the CSV.
5. **Model Definition:** Defines the `DecoderOnlyTransformer` architecture and a wrapper class (`DecoderOnlyModelWrapper`) that includes the model, optimizer, and loss function. Also defines the RNN model.
6. **Training Loop:** Implements the training process, including validation, loss calculation, early stopping, and plotting of training/validation loss.
7. **Testing:** Includes several test functions to verify basic model functionality (forward pass, handling different inputs).
8. **Evaluation:** Defines functions to compute and visualize a confusion matrix and calculate precision, recall, and F1-score.
9. **Main Execution:** Orchestrates the entire workflow: loading data, training the tokenizer, initializing the model, running tests, training the model, evaluating performance, and saving the trained model and reports.
10. **Logging:** Redirects output to both the console and a `log.txt` file.

This notebook also trains a KNN and Random Forest model to compare classification performance as baseline models.

1.1 Imports and Setup

Import necessary libraries. We check if `torch` and `tokenizers` are available and set flags accordingly.

[1]:
```
%pip install pandas numpy matplotlib scikit-learn torch tokenizers seaborn␣
↪oauth2client gdown pytorch-lightning lightning-bolts
```

```
Defaulting to user installation because normal site-packages is not
writeableNote: you may need to restart the kernel to use updated packages.

Requirement already satisfied: pandas in c:\users\pilchj\appdata\local\packages\
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Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\pilchj\appdata
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cal-packages\python312\site-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in c:\users\pilchj\appdata\local\pac
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Requirement already satisfied: packaging>=20.0 in c:\users\pilchj\appdata\local\
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packages\python312\site-packages (from matplotlib) (24.1)
Requirement already satisfied: pillow>=8 in c:\users\pilchj\appdata\local\packag
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al\packages\pythonsoftwarefoundation.python.3.12_qbz5n2kfra8p0\localcache\local-
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Requirement already satisfied: huggingface-hub<1.0,>=0.16.4 in c:\users\pilchj\a
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Requirement already satisfied: torchvision>=0.10.0 in c:\users\pilchj\appdata\lo
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Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in c:\users
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Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\pilchj\appda
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Requirement already satisfied: idna<4,>=2.5 in c:\users\pilchj\appdata\local\pac
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Requirement already satisfied: propcache>=0.2.0 in c:\users\pilchj\appdata\local
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aiohttp!=4.0.0a0,!=4.0.0a1->fsspec[http]>2021.06.0->pytorch-lightning) (1.18.3)
```

[2]:
```
import sys
import os
import math
import re
import csv
import io
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

```
from sklearn.metrics import precision_score, recall_score, f1_score,␣
 ↪accuracy_score, classification_report
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.ensemble import RandomForestClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV
import json # For writing the notebook itself

import torch
import torch.nn as nn
import torch.optim as optim
from tokenizers import Tokenizer
from tokenizers.models import BPE
from tokenizers.trainers import BpeTrainer
from tokenizers.pre_tokenizers import Whitespace

# Global variables for device and tokenizer
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
```

1.2 Data Import

[3]:
```
import os
import csv
import io

csv_file_path = "food_predictions.csv"

# Check if running in Colab
try:
    import google.colab
    is_colab = True
except ImportError:
    is_colab = False

if is_colab:
    # Colab-specific code
    try:
        from google.colab import drive
        from google.colab import auth
        from oauth2client.client import GoogleCredentials

        # Mount Google Drive
        drive.mount('/content/drive')

        # Authenticate with Google Drive
```

```
        auth.authenticate_user()
        gauth = GoogleCredentials.get_application_default()

        # File ID from Google Drive URL
        file_id = '1RFhhiSFwPOs6Y7y4yWCkegXlVaEYqHOB'  # Replace with the␣
↪actual file ID
        drive_file_path = f'/content/drive/MyDrive/food_predictions.csv'  #␣
↪Update the path if necessary

        # Check if CSV exists locally, or download from Google Drive
        if not os.path.exists(csv_file_path):
            try:
                # Download file from Google Drive
                import subprocess
                subprocess.run(['gdown', '--id', file_id, '-O', csv_file_path],␣
↪check=True)
                print(f"[INFO] Downloaded '{csv_file_path}' from Google Drive.")
            except Exception as e:
                print(f"[ERROR] Failed to download from Google Drive: {e}")
                raise FileNotFoundError(f"Could not download or find␣
↪'{csv_file_path}'. Please ensure the file ID and path are correct.")
        else:
            print(f"[INFO] Found existing '{csv_file_path}' in Colab. Using␣
↪this file.")
    except ImportError:
        print("[WARN] Google Colab modules not available but detected in Colab␣
↪environment.")
else:
    # Local environment (VS Code, etc.)
    if os.path.exists(csv_file_path):
        print(f"[INFO] Found existing '{csv_file_path}' locally. Using this␣
↪file.")
    else:
        # Create a simple placeholder CSV if it doesn't exist
        try:
            with open(csv_file_path, 'w', newline='') as f:
                writer = csv.writer(f)
                writer.writerow(['food_description', 'contains_allergen',␣
↪'sweetener', 'fats_oils'])
                writer.writerow(['Sample food item 1', 'True', 'sugar', 'olive␣
↪oil'])
                writer.writerow(['Sample food item 2', 'False', 'none', 'none'])
            print(f"[INFO] Created placeholder '{csv_file_path}' for local␣
↪development.")
            print("[NOTE] Replace this with your actual data file for␣
↪meaningful results.")
```

```
        except Exception as e:
            print(f"[ERROR] Failed to create placeholder CSV: {e}")
            raise
```

```
[INFO] Found existing 'food_predictions.csv' locally. Using this file.
```

2 Data Exploration

Let's explore the data to understand the distribution and structure of the dataset.

[4]:
```
df = pd.read_csv(csv_file_path)

print("DF Head")
df.head()
```

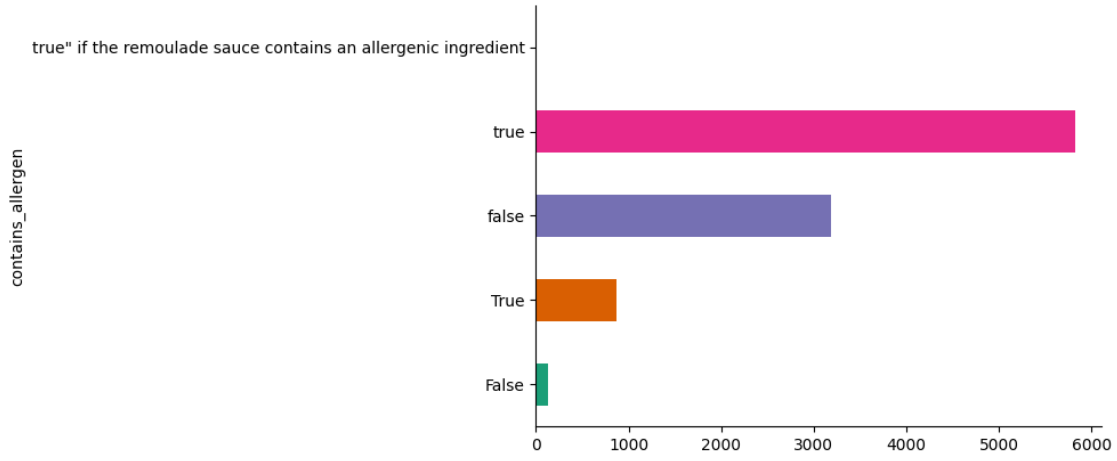
```
DF Head
```

[4]:

	food_description	main_ingredient	sweetener	fat_or_oil	seasoning	allergens	contains_allergen
0	Creamy scrambled eggs, crispy bacon, and toast…	Eggs	NaN	NaN	Bacon	Dairy, Eggs	true
1	omg best pizza i ever had: gooey melted mozzar…	Mozzarella	NaN	NaN	Tomato sauce, Crispy crust	Dairy, Wheat	true
2	Warm, flaky croissants filled with buttery, ga…	Spinach	NaN	Butter	Garlic	Almond, Dairy	True
3	Decadent chocolate cake, moist and rich, serve…	Chocolate	Sugar	NaN	NaN	Dairy	true
4	Fresh catch of the day: pan-seared salmon with…	salmon	NaN	NaN	lemon, herb	Fish	true

[5]:
```
# @title contains_allergen

from matplotlib import pyplot as plt
import seaborn as sns
df.groupby('contains_allergen').size().plot(kind='barh', color=sns.palettes.
 ↪mpl_palette('Dark2'))
plt.gca().spines[['top', 'right',]].set_visible(False)
```



Let's look at the factor data types

[6]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10020 entries, 0 to 10019
Data columns (total 7 columns):
 #   Column             Non-Null Count  Dtype
---  ------             --------------  -----
 0   food_description   10020 non-null  object
 1   main_ingredient    9865 non-null   object
 2   sweetener          3666 non-null   object
 3   fat_or_oil         3501 non-null   object
 4   seasoning          7891 non-null   object
 5   allergens          7548 non-null   object
 6   contains_allergen  10020 non-null  object
dtypes: object(7)
memory usage: 548.1+ KB
```

Let's look at the number of unique values for each factor. Most noteworthy, the food_descriptions are almost all unique, which is expected. And all of the samples have a value in the contains_allergen column.

[7]:
```
df.describe()
```

[7]:
```
                                        food_description main_ingredient  \
count                                              10020            9865
unique                                              9988             988
top     Fried chicken tenders with honey mustard dippi…         chicken
freq                                                   2             895

       sweetener fat_or_oil seasoning allergens contains_allergen
```

```
count       3666       3501       7891       7548              10020
unique       578        469       2778       1587                  5
top        Sugar     Butter       none      Dairy               true
freq         497        721        285       1547               5821
```

There appears to be a majority of items that either don't have a predicted sweetner or fat/oil.

[8]:
```
df.isnull().sum()
```

[8]:
```
food_description        0
main_ingredient       155
sweetener            6354
fat_or_oil           6519
seasoning            2129
allergens            2472
contains_allergen       0
dtype: int64
```

2.1 BPE Tokenizer

This class handles tokenization. It uses the `tokenizers` library to train a Byte-Pair Encoding (BPE) model on the provided text data. BPE is effective at handling unknown words by breaking them down into subword units.

If the `tokenizers` library is unavailable, it falls back to a simple character-level tokenizer.

[9]:
```
class BPETokenizer:
    """ Wrapper for BPE Tokenizer"""
    def __init__(self, texts):
        """ Initializes and trains the tokenizer.

        Args:
            texts (iterable): An iterable of strings to train the tokenizer on.
        """
        # Ensure all texts are strings
        texts = [str(text) for text in texts]

        # Use Hugging Face tokenizers library
        self.tokenizer = Tokenizer(BPE(unk_token="<unk>"))
        self.tokenizer.pre_tokenizer = Whitespace()
        # Define special tokens, ensuring <pad> is handled correctly (often ID␣
↪0 by convention)
        trainer = BpeTrainer(special_tokens=["<pad>", "<bos>", "<eos>",␣
↪"<unk>"])
        # Train the tokenizer
        self.tokenizer.train_from_iterator(texts, trainer=trainer)
        # Ensure pad token ID is 0 if possible (it usually is by default with␣
↪BpeTrainer)
```

```
        pad_token_id = self.tokenizer.token_to_id("<pad>")
        if pad_token_id is None:
              print("[WARN] <pad> token not found after training!")
              # Handle this case if necessary, maybe re-train or add manually
        elif pad_token_id != 0:
              print(f"[WARN] <pad> token ID is {pad_token_id}, not 0.␣
↪CrossEntropyLoss might need ignore_index adjustment if not using 0.")
        print(f"[INFO] Trained BPE tokenizer. Vocab size: {self.tokenizer.
↪get_vocab_size()}")

    def encode(self, text):
        # Ensure input is a string
        text = str(text)

        # Encode with BOS and EOS tokens implicitly handled via format string␣
↪during encoding
        bos_token = self.tokenizer.token_to_id("<bos>")
        eos_token = self.tokenizer.token_to_id("<eos>")

        encoded = self.tokenizer.encode(text) # Encode the main text

        # Manually add BOS and EOS if not added automatically or if specific␣
↪placement is needed
        output_ids = []
        if bos_token is not None:
            output_ids.append(bos_token)
        output_ids.extend(encoded.ids)
        if eos_token is not None:
              output_ids.append(eos_token)
        return output_ids

    def decode(self, ids):
        """ Decodes a list of token IDs back into a string. """
        # Ensure ids is a list of integers
        if isinstance(ids, torch.Tensor):
            ids = ids.cpu().tolist()
        # Use the tokenizer's decode method
        return self.tokenizer.decode(ids, skip_special_tokens=False) # Keep␣
↪special tokens for clarity if needed

    @property
    def vocab_size(self):
        """ Returns the size of the vocabulary. """
        return self.tokenizer.get_vocab_size()

    def token_to_id(self, token):
        """ Converts a token string to its ID."""
```

```
        return self.tokenizer.token_to_id(token)

    def id_to_token(self, id):
        """ Converts a token ID to its string representation."""
        return self.tokenizer.id_to_token(id)

    @property
    def pad_id(self):
        """ Returns the ID of the padding token."""
        return self.token_to_id("<pad>")
```

2.2 Dataset and Collation

2.2.1 `VectorizedFoodDataset` Class

Reads the `food_prediction.csv` file. It takes the `food_description` column and vectorizes it. The `contains_allergen` is then encoded to use 1 and 0 instead of true and false.

2.2.2 `FoodDataset` Class

Reads the `food_predictions.csv` file. It assumes the first column is `food_description` and concatenates all other columns into a structured `OUTPUT:` section. It then tokenizes this combined text.

2.2.3 `collate_fn` Function

Takes a batch of sequences (lists of token IDs) from the dataset and pads them to the length of the longest sequence in the batch. It creates an attention mask to indicate which tokens are real and which are padding. This is necessary for batch processing in PyTorch.

[10]:
```
class VectorizedFoodDataset:
    def __init__(self, csv_path, vectorizer):
        df = pd.read_csv(csv_path)

        # Convert descriptions to strings to ensure they can be processed by␣
↪vectorizer
        descriptions = [str(desc) for desc in df["food_description"].tolist()]

        # Convert allergen information to boolean values more reliably
        bool_array = np.array([(str(val).lower() == "true") for val in␣
↪df["contains_allergen"].tolist()], dtype=int)

        self.targets = bool_array
        self.features = vectorizer.fit_transform(descriptions)

    def __len__(self):
        return len(self.targets)

    def __getitem__(self, idx):
```

```
        return self.features[idx], self.targets[idx]

    def __clean_text(text):
        """Cleans the input text by removing irrelevant characters and␣
↪converting to lowercase."""
        text = re.sub(r'[^\w\s]', '', str(text))  # Remove punctuation, ensure␣
↪text is string
        text = text.lower()  # Convert to lowercase
        return text


class FoodDataset:
    """ Loads and preprocesses data from the food CSV file."""
    def __init__(self, csv_path, max_len=128):
        """ Initializes the dataset.

        Args:
            csv_path (str): Path to the input CSV file.
            max_len (int): Maximum sequence length after tokenization. Longer␣
↪sequences will be truncated.
        """
        self.samples = []
        self._tokenizer = None # Tokenizer will be set later
        self.max_len = max_len

        try:
            with open(csv_path, "r", encoding="utf-8") as f:
                rows = list(csv.DictReader(f))
        except FileNotFoundError:
            print(f"[ERROR] CSV file not found at {csv_path}. Please ensure it␣
↪exists.")
            rows = [] # Initialize with empty list to prevent further errors
        except Exception as e:
             print(f"[ERROR] Failed to read CSV file {csv_path}: {e}")
             rows = []

        for row in rows:
            desc = row.get("food_description", "") # Get food description,␣
↪default to empty string if missing
            other_cols = []
            for k, v in row.items():
                if k == "food_description": # Skip the description itself
                    continue
                other_cols.append(f"{k}: {v}") # Format other columns as 'key:␣
↪value'
```

```
            # Combine description and other info into a single string
            output_section = "\n".join(other_cols)
            # Using a separator like ' OUTPUT:' helps the model distinguish␣
↪input from target
            self.samples.append(desc.strip() + "\nOUTPUT:\n" + output_section.
↪strip())

        if not self.samples:
            print("[WARN] No samples loaded from the CSV. The dataset is empty.
↪")
        else:
             print(f"[INFO] Loaded {len(self.samples)} samples from {csv_path}.
↪")

    def set_tokenizer(self, tokenizer):
        """ Sets the tokenizer to be used for encoding samples. """
        self._tokenizer = tokenizer
        print("[INFO] Tokenizer set for the dataset.")

    def __len__(self):
        """ Returns the number of samples in the dataset. """
        return len(self.samples)

    def __getitem__(self, idx):
        """ Retrieves a single sample by index.

        If a tokenizer is set, it returns the tokenized and truncated sequence.
        Otherwise, it returns the raw text sample.
        """
        text = self.samples[idx]
        if not self._tokenizer:
            # Return raw text if tokenizer is not set (e.g., during tokenizer␣
↪training)
            return text

        # Encode the text using the tokenizer
        enc = self._tokenizer.encode(text)

        # Truncate if the encoded sequence exceeds max_len
        if len(enc) > self.max_len:
            # Truncate, but ensure EOS token is preserved if it was originally␣
↪included
            eos_id = self._tokenizer.token_to_id("<eos>")
            enc = enc[:self.max_len -1 ] + [eos_id]

        return enc
```

```
def collate_fn(batch, tokenizer):
    """ Collates a batch of tokenized sequences into padded tensors. """
    if not batch:
        # Handle empty batch case
        return {"input_ids": torch.empty((0, 0), dtype=torch.long),
                "attention_mask": torch.empty((0, 0), dtype=torch.long)}

    # Check if the batch contains raw strings (shouldn't happen if used after␣
 ↪tokenization)
    if isinstance(batch[0], str):
        print("[WARN] collate_fn received strings, expected token IDs.")
        return {"input_ids": batch, "attention_mask": [None]*len(batch)} #␣
 ↪Basic handling for unexpected strings

    # Determine the maximum length in the batch
    lengths = [len(x) for x in batch]
    max_batch_len = max(lengths) if lengths else 0

    # Look up the padding token ID from the tokenizer
    pad_token_id = tokenizer.pad_id

    # Create padded tensors initialized with the padding token ID
    padded = torch.full((len(batch), max_batch_len), pad_token_id, dtype=torch.
 ↪long)
    # Create attention mask (1 for real tokens, 0 for padding)
    mask = torch.zeros((len(batch), max_batch_len), dtype=torch.long)

    # Fill the tensors with data from the batch
    for i, seq in enumerate(batch):
        seqlen = len(seq)
        padded[i, :seqlen] = torch.tensor(seq, dtype=torch.long)
        mask[i, :seqlen] = 1 # Mark the actual tokens in the mask

    return {"input_ids": padded, "attention_mask": mask}
```

2.3 Model Architecture

2.3.1 `DecoderOnlyTransformer`

Implements a standard Transformer Decoder stack. It includes: - An embedding layer (`nn.Embedding`) to convert token IDs into vectors. - A stack of Transformer Decoder Layers (`nn.TransformerDecoderLayer`, `nn.TransformerDecoder`). - A final linear layer (`nn.Linear`) to project the decoder output back to the vocabulary size, producing logits. - It uses a causal mask (`generate_square_subsequent_mask`) to ensure that predictions for a position can only depend on previous positions.

2.3.2 `DecoderOnlyModelWrapper`

A wrapper class that contains the `DecoderOnlyTransformer` model, the Adam optimizer, and the cross-entropy loss function (`nn.CrossEntropyLoss`). It provides methods for: - Running the forward pass. - Calculating the loss (using teacher forcing: predicting the next token based on the ground truth previous tokens). - Accessing the optimizer.

[11]:
```
import torch.nn as nn

class DecoderOnlyTransformer(nn.Module):
    """ Simple Decoder-Only Transformer model. """
    def __init__(self, vocab_size, d_model=128, nhead=4, num_layers=5,␣
↪dim_feedforward=512):
        super().__init__()
        self.d_model = d_model
        # Embedding layer: maps token IDs to dense vectors
        self.emb = nn.Embedding(vocab_size, d_model)
        # Positional Encoding (Add this for better performance, simple example␣
↪omits it)
        self.pos_encoder = nn.Embedding(vocab_size, d_model)

        # Standard Transformer Decoder Layer
        decoder_layer = nn.TransformerDecoderLayer(d_model=d_model, nhead=nhead,
                                                   ␣
↪dim_feedforward=dim_feedforward,
                                                    batch_first=True) # Use␣
↪batch_first=True
        # Stack multiple decoder layers
        self.decoder = nn.TransformerDecoder(decoder_layer,␣
↪num_layers=num_layers)

        # Output layer: maps decoder output back to vocabulary size (logits)
        self.fc = nn.Linear(d_model, vocab_size)

    def forward(self, x, attention_mask=None):
        """ Forward pass of the model.

        Args:
            x (Tensor): Input tensor of shape (batch_size, seq_len).
            attention_mask (Tensor, optional): Mask for padding tokens. Shape␣
↪(batch_size, seq_len).

        Returns:
            Tensor: Output logits of shape (batch_size, seq_len, vocab_size).
        """
        # 1. Embedding
```

```
        positions = torch.arange(0, x.size(1), dtype=torch.long, device=x.
↪device).unsqueeze(0)
        # Add positional encoding here if implemented
        pos_emb = self.pos_encoder(positions)
        emb = self.emb(x) + pos_emb

        # 2. Generate Causal Mask
        seq_len = x.size(1)
        # Mask to prevent attention to future tokens
        tgt_mask = nn.Transformer.generate_square_subsequent_mask(seq_len).to(x.
↪device)

        # 3. Generate Padding Mask from attention_mask
        # TransformerDecoderLayer expects mask where True indicates masking
        # Our `attention_mask` is 1 for tokens, 0 for padding. Need to invert␣
↪it.
        if attention_mask is not None:
            # Shape: (batch_size, seq_len)
            padding_mask = (attention_mask == 0)
        else:
            padding_mask = None

        # 4. Pass through Decoder
        # Note: TransformerDecoder uses target (tgt) and memory. For␣
↪decoder-only, memory is the same as target.
        # `batch_first=True` means input shape is (batch, seq, feature)
        dec_output = self.decoder(tgt=emb, memory=emb,
                                  tgt_mask=tgt_mask,
                                  tgt_key_padding_mask=padding_mask,
                                  memory_key_padding_mask=padding_mask) # Apply␣
↪padding mask to memory as well

        # 5. Final Linear Layer (Output Logits)
        # Output shape: (batch_size, seq_len, vocab_size)
        logits = self.fc(dec_output)

        return logits

def count_parameters(model):
    """ Counts the total number of trainable parameters in a PyTorch model. """
    # Ensure we are counting parameters of the actual nn.Module
    actual_model = model.model if isinstance(model, DecoderOnlyModelWrapper)␣
↪else model
    if isinstance(actual_model, nn.Module):
        return sum(p.numel() for p in actual_model.parameters() if p.
↪requires_grad)
```

```
    else:
        return 0 # Should not happen with real model

class DecoderOnlyModelWrapper(nn.Module):
    """ Wraps the Transformer model, optimizer, and loss function. """
    def __init__(self, vocab_size, d_model=128, nhead=4, num_layers=5,␣
 ↪dim_feedforward=512, lr=1e-3):
        super().__init__()
        self.model = DecoderOnlyTransformer(vocab_size, d_model, nhead,␣
 ↪num_layers, dim_feedforward)
        self.lr = lr
        # Adam optimizer for training
        self.optimizer = optim.Adam(self.model.parameters(), lr=lr)
        # Cross Entropy Loss, ignoring padding token (assuming ID 0)
        self.crit = nn.CrossEntropyLoss(ignore_index=0)
        print("[INFO] Initialized PyTorch DecoderOnlyModelWrapper.")

    def forward(self, x, attention_mask=None):
        """ Forward pass through the underlying model. """
        # Ensure input tensor is on the same device as the model
        # device = next(self.model.parameters()).device # Get device from model␣
 ↪parameters
        # x = x.to(device)
        # if attention_mask is not None:
        #     attention_mask = attention_mask.to(device)
        return self.model(x, attention_mask)

    def compute_loss(self, batch):
        """ Computes the loss for a given batch. """
        inp = batch["input_ids"] # Shape: (batch_size, seq_len)
        attn_mask = batch.get("attention_mask") # Shape: (batch_size, seq_len)␣
 ↪or None

        device = next(self.model.parameters()).device
        inp = inp.to(device)
        if attn_mask is not None:
            attn_mask = attn_mask.to(device)

        # Get model predictions (logits)
        # Input `inp` has shape (batch, seq_len)
        logits = self(inp, attention_mask=attn_mask) # Shape: (batch, seq_len,␣
 ↪vocab_size)

        # Prepare for loss calculation:
        # Predict the token at step `t` based on tokens `0..t-1`
        # Logits for prediction need to exclude the last token's output
        # Target labels need to exclude the first token (BOS)
```

```
        pred_logits = logits[:, :-1, :].contiguous() # Shape: (batch,␣
↪seq_len-1, vocab_size)
        target_ids = inp[:, 1:].contiguous()       # Shape: (batch, seq_len-1)

        # Flatten logits and targets for CrossEntropyLoss
        # Input shape for loss: (N*C), Target shape: (N)
        # N = batch_size * (seq_len - 1), C = vocab_size
        loss = self.crit(pred_logits.view(-1, pred_logits.size(-1)), target_ids.
↪view(-1))

        return loss

    def get_optimizer(self):
        """ Returns the optimizer instance. """
        return self.optimizer
```

2.4 Training Loop

The `train_loop` function orchestrates the training process over multiple epochs: - Iterates through the training data loader. - Computes the loss for each batch. - Performs backpropagation and updates model weights using the optimizer. - Optionally, evaluates the model on a validation set after each epoch. - Implements early stopping: training halts if the validation loss doesn't improve for a specified number of `patience` epochs. - Tracks and prints training and validation losses. - Plots the losses and saves the plot as `training_validation_loss.png`. - Generates a basic `report.html` containing the loss plot.

[12]:
```
def train_loop(model, train_loader_func, val_loader_func, epochs=30,␣
↪device="cpu", patience=5, report_filename='report.html',␣
↪loss_plot_filename='training_validation_loss.png'):
    """ Trains the model, performs validation, and handles early stopping. """

    # Move model to the specified device (CPU or GPU)
    model.to(device)

    # Enable mixed precision training if CUDA is available
    use_amp = device.type == 'cuda'
    scaler = torch.cuda.amp.GradScaler() if use_amp else None
    print(f"[INFO] Model moved to {device}. Mixed precision training:␣
↪{use_amp}")

    best_val_loss = float('inf')
    patience_counter = 0
    train_losses = []
    val_losses = []

    print(f"--- Starting Training --- Epochs: {epochs}, Device: {device},␣
↪Patience: {patience} ---")
```

```
    for epoch in range(epochs):
        print(f"\n=== Epoch {epoch+1}/{epochs} ===")

        # --- Training Phase ---
        model.train() # Set model to training mode
        total_train_loss = 0.0
        train_steps = 0
        train_loader = train_loader_func() # Get fresh iterator for the epoch

        print("  Training...")
        for i, batch in enumerate(train_loader):
            # training step
            try:
                # Calculate loss
                loss = model.compute_loss(batch)
                loss_item = loss.item()
                total_train_loss += loss_item

                # Backpropagation
                model.get_optimizer().zero_grad() # Clear previous gradients
                loss.backward()                   # Compute gradients
                model.get_optimizer().step()      # Update weights
            except Exception as e:
                  print(f"[ERROR] Exception during training step {i}: {e}")
                  # Optionally skip batch or break
                  continue

            train_steps += 1
            if (i + 1) % 10 == 0: # Print progress every 10 steps
                 print(f"    Step {i+1}: current batch loss = {loss_item:.4f}")

        avg_train_loss = total_train_loss / train_steps if train_steps > 0 else␣
↪0
        train_losses.append(avg_train_loss)
        print(f"  Epoch {epoch+1} Average Train Loss: {avg_train_loss:.4f}")

        # --- Validation Phase ---
        val_loader = val_loader_func() # Get validation loader
        if val_loader:
            print("  Validating...")
            model.eval() # Set model to evaluation mode

            total_val_loss = 0.0
            val_steps = 0

            # Use torch.no_grad() for validation to save memory and computation
```

```
            maybe_no_grad = torch.no_grad()

            with maybe_no_grad:
                for i, val_batch in enumerate(val_loader):
                    try:
                      vloss = model.compute_loss(val_batch)
                      vloss_item = vloss.item()
                    except Exception as e:
                        print(f"[ERROR] Exception during validation step {i}:␣
↪{e}")
                        vloss_item = float('nan') # Indicate error
                        continue

                    if not math.isnan(vloss_item):
                         total_val_loss += vloss_item
                         val_steps += 1
                         if (i + 1) % 10 == 0:
                             print(f"    Validation Step {i+1}: current batch␣
↪loss = {vloss_item:.4f}")

            avg_val_loss = total_val_loss / val_steps if val_steps > 0 else␣
↪float('inf') # Handle case with no validation steps
            val_losses.append(avg_val_loss)
            print(f"  Epoch {epoch+1} Average Validation Loss: {avg_val_loss:.
↪4f}")

            # --- Early Stopping Check ---
            if avg_val_loss < best_val_loss:
                best_val_loss = avg_val_loss
                patience_counter = 0 # Reset patience counter
                print(f"    New best validation loss: {best_val_loss:.4f}.␣
↪Patience reset.")
                # Save model state
                model_state = {
                    'model_state_dict': model.state_dict(),
                    'optimizer_state_dict': model.get_optimizer().state_dict(),
                    'epoch': epoch,
                    'best_val_loss': best_val_loss,
                    'train_losses': train_losses,
                    'val_losses': val_losses
                }
                torch.save(model_state, 'best_model.pth')
                print("    Best model checkpoint saved with additional training␣
↪state.")
            else:
                patience_counter += 1
```

```
                improvement = best_val_loss - avg_val_loss
                print(f"    Validation loss did not improve. Current:␣
↪{avg_val_loss:.4f}, Best: {best_val_loss:.4f}, Delta: {improvement:.6f}")
                print(f"    Early stopping patience: {patience_counter}/
↪{patience}")
                if patience_counter >= patience:
                    print(f"\n--- Early Stopping triggered at epoch {epoch+1}␣
↪---")
                    print(f"--- Best validation loss: {best_val_loss:.4f}␣
↪achieved at epoch {epoch+1 - patience_counter} ---")
                    break # Stop training
        else:
             print("  No validation loader provided, skipping validation.")

    print("\n--- Training Finished ---")

    # --- Plotting and Reporting ---
    try:
        plt.figure(figsize=(10, 5))
        plt.plot(train_losses, label='Train Loss')
        if val_losses: # Only plot validation loss if it was calculated
            plt.plot(val_losses, label='Validation Loss')
        plt.xlabel('Epochs')
        plt.ylabel('Loss')
        plt.title('Training and Validation Loss Over Epochs')
        plt.legend()
        plt.grid(True)
        plt.savefig(loss_plot_filename)
        plt.show() # Display the plot in the notebook
        print(f"[INFO] Loss plot saved as '{loss_plot_filename}'")

        # Generate HTML Report (overwrite or create)
        with open(report_filename, 'w') as f:
            f.write('<html><head><title>Training Report</title></head><body>\n')
            f.write('<h1>Training Report</h1>\n')
            f.write('<h2>Training and Validation Loss</h2>\n')
            # Use relative path for image source
            f.write(f'<img src="{os.path.basename(loss_plot_filename)}"␣
↪alt="Training and Validation Loss"><br>\n')
            # Table for losses (optional)
            f.write('<h3>Loss Values per Epoch</h3>\n')
            f.write('<table border="1"><tr><th>Epoch</th><th>Train Loss</th>')
            if val_losses:
                f.write('<th>Validation Loss</th>')
            f.write('</tr>\n')
            for i in range(len(train_losses)):
                 f.write(f'<tr><td>{i+1}</td><td>{train_losses[i]:.4f}</td>')
```

```
                if i < len(val_losses):
                    f.write(f'<td>{val_losses[i]:.4f}</td>')
                elif val_losses: # If val exists but stopped early
                     f.write('<td>N/A</td>')
                f.write('</tr>\n')
            f.write('</table>\n')
            # Placeholder for closing tags, will be added to by evaluation␣
↪metrics
            # f.write('</body></html>')
        print(f"[INFO] Basic HTML report started in '{report_filename}'")

    except Exception as e:
         print(f"[ERROR] Failed to generate plot or report: {e}")

    return train_losses, val_losses # Return recorded losses
```

2.5 Create an RNN Model for comparison

[13]:
```
import pytorch_lightning as pl
import torch
from torch import nn

class RNNModel(pl.LightningModule):
    def __init__(self, vocab_size, embedding_dim=128, hidden_units=128,␣
↪dropout_rate=0.2, lr=1e-3):
        super().__init__()
        self.save_hyperparameters() # Automatically saves the hyperparameters

        self.embedding = nn.Embedding(vocab_size, embedding_dim)
        self.rnn = nn.GRU(embedding_dim, hidden_units, batch_first=True)
        self.dropout = nn.Dropout(dropout_rate)
        self.fc = nn.Linear(hidden_units, 1) # For binary classification
        self.lr = lr

    def forward(self, x):
        x = self.embedding(x)
        x, _ = self.rnn(x) # Get the last hidden state
        x = self.dropout(x[:, -1, :]) # Apply dropout to the last hidden state
        x = self.fc(x)
        return x

    def training_step(self, batch, batch_idx):
        x, y = batch
        logits = self(x)
        loss = nn.BCEWithLogitsLoss()(logits.squeeze(), y.float()) # Binary␣
↪cross-entropy loss
        self.log('train_loss', loss)
```

```
        return loss

    def validation_step(self, batch, batch_idx):
        x, y = batch
        logits = self(x)
        loss = nn.BCEWithLogitsLoss()(logits.squeeze(), y.float())
        self.log('val_loss', loss)

    def configure_optimizers(self):
        return torch.optim.Adam(self.parameters(), lr=self.lr)
```

2.6 Evaluation Functions

These functions evaluate the trained model's performance on a dataset (typically the validation or a separate test set).

2.6.1 `compute_confusion_matrix`

- Iterates through the evaluation dataset.
- Gets model predictions (logits) for each batch.
- Determines the predicted token ID (argmax) for each position.
- Compares predicted IDs against the true next token IDs (gold labels).
- Aggregates these comparisons into a confusion matrix (tensor).
- Visualizes the confusion matrix using `matplotlib` and saves it as `confusion_matrix.png`.

2.6.2 `compute_metrics`

- Similar to the confusion matrix computation, it iterates through the data and gets predictions vs. gold labels.
- Flattens the predictions and labels across all batches (ignoring padding).
- Uses `scikit-learn`'s `precision_score`, `recall_score`, and `f1_score` functions to calculate weighted metrics across all token classes.
- Returns the computed precision, recall, and F1 score.

[14]:
```
def compute_confusion_matrix(model, eval_dataset, tokenizer, device="cpu",␣
↪batch_size=8, conf_matrix_filename='confusion_matrix.png'):
    """ Computes and saves the confusion matrix for token predictions. """
    print("--- Computing Confusion Matrix ---")

    model.eval() # Ensure model is in evaluation mode
    model.to(device) # Ensure model is on the correct device

    vocab_size = model.model.fc.out_features
    # Initialize confusion matrix on CPU to avoid potential GPU memory issues␣
↪for large vocabs
    confusion = torch.zeros((vocab_size, vocab_size), dtype=torch.long,␣
↪device='cpu')
```

```
    # Create a simple data loader for the evaluation dataset
    def eval_loader_func():
        for i in range(0, len(eval_dataset), batch_size):
            batch_data = eval_dataset[i : i + batch_size]
            # Collate the batch manually or using the collate_fn
            collated_batch = collate_fn(batch_data, tokenizer)
            yield collated_batch

    processed_tokens = 0
    with torch.no_grad(): # Disable gradient calculations
        for batch in eval_loader_func():
            inp = batch["input_ids"].to(device)
            attn_mask = batch.get("attention_mask", None)
            if attn_mask is not None:
                 attn_mask = attn_mask.to(device)

            if inp.numel() == 0: continue # Skip empty batches

            # Get model predictions
            logits = model(inp, attention_mask=attn_mask) # (batch, seq_len,␣
↪vocab_size)

            # Get predicted token IDs (argmax along the vocab dimension)
            # We predict the next token, so compare logits[:, :-1, :] with␣
↪targets[:, 1:]
            pred_logits = logits[:, :-1, :]
            predicted_ids = pred_logits.argmax(dim=-1) # (batch, seq_len-1)

            # Get gold standard (actual) token IDs
            gold_ids = inp[:, 1:] # (batch, seq_len-1)

            # Create a mask to ignore padding tokens in the gold standard
            # Assuming pad_id is 0
            mask = (gold_ids != tokenizer.pad_id) # (batch, seq_len-1)

            # Flatten tensors and apply mask
            gold_flat = torch.masked_select(gold_ids, mask)
            pred_flat = torch.masked_select(predicted_ids, mask)

            # Move tensors to CPU for confusion matrix update
            gold_flat_cpu = gold_flat.cpu()
            pred_flat_cpu = pred_flat.cpu()

            # Update confusion matrix
            for gold_tok, pred_tok in zip(gold_flat_cpu, pred_flat_cpu):
                # Ensure indices are within bounds (should be guaranteed by␣
↪vocab size)
```

```
                if 0 <= gold_tok.item() < vocab_size and 0 <= pred_tok.item() <␣
↪vocab_size:
                    confusion[gold_tok.item(), pred_tok.item()] += 1
                    processed_tokens += 1
                else:
                    print(f"[WARN] Token ID out of bounds: Gold={gold_tok.
↪item()}, Pred={pred_tok.item()}. Vocab size={vocab_size}. Skipping.")
            print(f"  Processed batch. Total tokens considered so far:␣
↪{processed_tokens}")

    print(f"--- Confusion Matrix Calculation Complete. Total tokens analyzed:␣
↪{processed_tokens} ---")

    # Plotting the confusion matrix
    try:
        plt.figure(figsize=(10, 10))
        # Display a subset if the vocab is too large
        matrix_to_plot = confusion
        max_display_size = 50 # Limit display size for readability
        if vocab_size > max_display_size:
            print(f"[INFO] Vocab size ({vocab_size}) is large, plotting only␣
↪top {max_display_size}x{max_display_size} part of the matrix.")
            matrix_to_plot = confusion[:max_display_size, :max_display_size]

        plt.imshow(matrix_to_plot.log1p(), interpolation='nearest',␣
↪cmap='Blues') # Use log scale for better visibility
        plt.title(f'Confusion Matrix (Log Scale) - First {matrix_to_plot.
↪shape[0]} Tokens')
        plt.xlabel('Predicted Token ID')
        plt.ylabel('Actual Token ID')
        plt.colorbar()
        # Add ticks if the matrix is small enough
        if matrix_to_plot.shape[0] <= 20:
            tick_marks = torch.arange(matrix_to_plot.shape[0])
            plt.xticks(tick_marks, tick_marks)
            plt.yticks(tick_marks, tick_marks)

        plt.tight_layout()
        plt.savefig(conf_matrix_filename)
        plt.show()
        print(f"[INFO] Confusion matrix plot saved as '{conf_matrix_filename}'")
    except Exception as e:
        print(f"[ERROR] Failed to plot confusion matrix: {e}")

    # Optionally, return the matrix itself
    return confusion
```

```python
def compute_metrics(model, eval_dataset, tokenizer, device="cpu", batch_size=8):
    """ Computes precision, recall, and F1 score for token predictions. """
    print("--- Computing Metrics (Precision, Recall, F1) ---")

    model.eval() # Ensure model is in evaluation mode
    model.to(device) # Ensure model is on the correct device

    all_preds = []
    all_labels = []

    # Create a simple data loader for the evaluation dataset
    def eval_loader_func():
        for i in range(0, len(eval_dataset), batch_size):
            batch_data = []
            for j in range(i, min(i + batch_size, len(eval_dataset))):
                item = eval_dataset[j]
                # Ensure we're working with sequence data, not scalars
                if isinstance(item, (list, tuple)) or (hasattr(item, "__len__")␣
 ↪and not isinstance(item, (str, int, float))):
                    batch_data.append(item)
                else:
                    # Skip scalar values or convert them if needed
                    print(f"[WARN] Skipping non-sequence item at index {j}:␣
 ↪{item}")

            if not batch_data:
                continue  # Skip empty batches

            # Process the batch through collate_fn
            try:
                collated_batch = collate_fn(batch_data, tokenizer)
                yield collated_batch
            except Exception as e:
                print(f"[ERROR] Failed to process batch {i//batch_size}: {e}")
                continue

    processed_tokens = 0
    with torch.no_grad():
        for batch in eval_loader_func():
            inp = batch["input_ids"].to(device)
            attn_mask = batch.get("attention_mask", None)
            if attn_mask is not None:
                 attn_mask = attn_mask.to(device)

            if inp.numel() == 0: continue # Skip empty batches
```

```
            logits = model(inp, attention_mask=attn_mask)
            pred_logits = logits[:, :-1, :]
            predicted_ids = pred_logits.argmax(dim=-1)
            gold_ids = inp[:, 1:]
            mask = (gold_ids != tokenizer.pad_id)

            gold_flat = torch.masked_select(gold_ids, mask)
            pred_flat = torch.masked_select(predicted_ids, mask)

            # Append flattened results (move to CPU list for scikit-learn)
            all_labels.extend(gold_flat.cpu().tolist())
            all_preds.extend(pred_flat.cpu().tolist())
            processed_tokens += len(gold_flat)
            print(f"  Processed batch. Total tokens considered so far:␣
↪{processed_tokens}")

    print(f"--- Metrics Calculation Complete. Total tokens analyzed:␣
↪{processed_tokens} ---")

    if not all_labels: # Handle case where no valid tokens were processed
        print("[WARN] No valid tokens found for metric calculation. Returning␣
↪zero metrics.")
        return 0.0, 0.0, 0.0

    # Compute metrics using scikit-learn
    # 'weighted' average accounts for label imbalance
    # `zero_division=0` handles cases where a class might have no predictions/
↪labels
    try:
        precision = precision_score(all_labels, all_preds, average='weighted',␣
↪zero_division=0)
        recall = recall_score(all_labels, all_preds, average='weighted',␣
↪zero_division=0)
        f1 = f1_score(all_labels, all_preds, average='weighted',␣
↪zero_division=0)
        print(f"  Calculated Metrics - Precision: {precision:.4f}, Recall:␣
↪{recall:.4f}, F1 Score: {f1:.4f}")
    except Exception as e:
         print(f"[ERROR] Failed to compute metrics using sklearn: {e}")
         precision, recall, f1 = 0.0, 0.0, 0.0 # Default to zero on error

    return precision, recall, f1
```

2.7 Logging Utility

The `Tee` class redirects `stdout` and `stderr` streams. Any output printed to the console will also be written to a specified log file (`log.txt` in this case). This is useful for keeping a persistent record of the entire process, including print statements, warnings, and errors.

[15]:
```python
class Tee:
    """ Utility class to redirect stdout/stderr to both console and a file."""
    def __init__(self, console, logfile):
        self.console = console
        self.logfile = logfile

    def write(self, data):
        self.console.write(data)
        self.logfile.write(data)

    def flush(self):
        # This flush method is needed for compatibility with sys.stdout
        self.console.flush()
        self.logfile.flush()
```

2.8 Main Execution Block

This is the main part of the notebook that orchestrates the entire process:

1. **Setup Logging:** Redirects output using the `Tee` class to `log.txt`.
2. **Load Dataset:** Creates an instance of `FoodDataset` using `food_predictions.csv`.
3. **Test Dataset:** Runs `test_dataset_length`.
4. **Initialize & Train Tokenizer:** Creates `BPETokenizer` and trains it on the dataset samples.
5. **Set Tokenizer for Dataset:** Assigns the trained tokenizer to the dataset instance.
6. **Data Split:** Splits dataset indices into training and validation sets (using a simple 90/10 split here).
7. **Define Data Loaders:** Creates functions (`train_loader`, `val_loader`) that generate batches of data using the specified indices and the `collate_fn`.
8. **Initialize Model:** Creates an instance of `DecoderOnlyModelWrapper` with the vocabulary size from the tokenizer and hyperparameters.
9. **Set Device:** Determines whether to use CUDA (GPU) if available, otherwise CPU.
10. **Count Parameters & Run Tests:** Prints the number of trainable parameters and runs the basic model tests.
11. **Train Model:** Calls the `train_loop` function to train the model.
12. **Evaluate Model:** After training, calls `compute_confusion_matrix` and `compute_metrics` on the validation set (used here as a test set).
13. **Save Model & Report:** Saves the trained model's state dictionary to `trained_model.pth` and appends the evaluation metrics to `report.html`.
14. **Cleanup Logging:** Restores the original `stdout` and `stderr`.

[16]:
```python
# Define filenames
log_filename = "log.txt"
csv_filename = "food_predictions.csv" # Assumed to be created or exist
```

```
report_filename = "report.html"
loss_plot_filename = "training_validation_loss.png"
conf_matrix_filename = "confusion_matrix.png"
model_save_filename = "trained_model.pth"

# Clear log file at the start
try:
    with open(log_filename, "w") as f:
        f.write("--- Log Start ---\n")
    print(f"[INFO] Cleared log file: {log_filename}")
except IOError as e:
     print(f"[WARN] Could not clear log file {log_filename}: {e}")

# Keep original stdout/stderr
original_stdout = sys.stdout
original_stderr = sys.stderr
```

```
[INFO] Cleared log file: log.txt
```

[17]:
```
def test_dataset_length(dataset):
    """ A simple test function to check the length of the dataset. """
    print(f"[INFO] Dataset length: {len(dataset)}")

# Open log file in append mode and start Tee redirection
try:
    log_file = open(log_filename, "a", encoding='utf-8')
    sys.stdout = Tee(original_stdout, log_file)
    sys.stderr = Tee(original_stderr, log_file)

    print("\n--- Starting Main Process ---")

    # 1. Load Dataset
    print(f"\n[Phase 1] Loading dataset from '{csv_filename}'...")
    vectorizer = TfidfVectorizer()
    vector_dset = VectorizedFoodDataset(csv_filename, vectorizer)

    # 2. Test Vectorized Dataset Length
    print(f"\n[Phase 2] Vectorizing dataset...")
    test_dataset_length(vector_dset)
    if len(vector_dset) == 0:
        raise ValueError("Dataset is empty. Cannot proceed. Check CSV file and␣
 ↪path.")

    # 3. Print Features and Targets for first sample
    print(f"\n[Phase 3] Check vectorized data")
    features, target = vector_dset[0]
    print(f"  Features: {features}")
```

```
    print(f"  Target: {target}")

    # 4a. Split data into training and testing sets
    print("\n[Phase 4a] Splitting data into training and testing sets...")
    X_train, X_test, y_train, y_test = train_test_split(
        vector_dset.features, vector_dset.targets, test_size=0.2,␣
↪random_state=42
    )
    print(f"  Training Features shape: {X_train.shape}")
    print(f"  Training Targets shape: {y_train.shape}")
    print(f"  Testing Features shape: {X_test.shape}")
    print(f"  Testing Targets shape: {y_test.shape}")

    # 4b. Scale features for kNN
    print("\n[Phase 4b] Scaling features for kNN...")
    scaler = StandardScaler(with_mean=False)

    X_train_scaled = scaler.fit_transform(X_train)
    X_test_scaled = scaler.transform(X_test)

    # 5a. Initialize and train Random Forest
    random_forest_param_grid = {
        'n_estimators': [50, 100, 200],
        'max_depth': [None, 10, 20],
        'min_samples_split': [2, 5, 10],
        'min_samples_leaf': [1, 2, 4]
    }

    print("\n[Phase 5a] Hyperparameter tuning for Random Forest...")
    random_forest_grid_search =␣
↪GridSearchCV(RandomForestClassifier(random_state=42),␣
↪random_forest_param_grid, cv=5, scoring='accuracy')
    random_forest_grid_search.fit(X_train, y_train)
    random_forest_model = random_forest_grid_search.best_estimator_
    print(f"Best Random Forest parameters: {random_forest_grid_search.
↪best_params_}")

    # 5b. Initialize and train kNN
    kNN_param_grid = {
        'n_neighbors': [3, 5, 7, 9],
        'weights': ['uniform', 'distance'],
        'metric': ['euclidean', 'manhattan']
    }

    print("\n[Phase 5b] Hyperparameter tuning for K-Nearest Neighbors...")
    kNN_grid_search = GridSearchCV(KNeighborsClassifier(), kNN_param_grid,␣
↪cv=5, scoring='accuracy')
```

```
    kNN_grid_search.fit(X_train_scaled, y_train)
    kNN_model = kNN_grid_search.best_estimator_
    print(f"Best kNN parameters: {kNN_grid_search.best_params_}")

    # 6a. Make predictions on testing set for Random Forest
    print("\n[Phase 6a] Running prediction on Random Forest...")
    random_forest_y_pred = random_forest_model.predict(X_test)

    # 6b. Make predictions on testing set for kNN
    print("\n[Phase 6b] Running prediction on K-Nearest Neighbors...")
    kNN_y_pred = kNN_model.predict(X_test_scaled)

    # 7a. Evaluate performance of Random Forest
    print("\n[Phase 7a] Evaluate performance of Random Forest...")
    random_forest_accuracy = accuracy_score(y_test, random_forest_y_pred)
    print(f"Random Forest Accuracy: {random_forest_accuracy}")
    print(classification_report(y_test, random_forest_y_pred))

    # 7b. Evaluate performance of kNN
    print("\n[Phase 7b] Evaluate performance of K-Nearest Neighbors...")
    kNN_accuracy = accuracy_score(y_test, kNN_y_pred)
    print(f"K-Nearest Neighbor Accuracy: {kNN_accuracy}")
    print(classification_report(y_test, kNN_y_pred))

finally:
    # 13. Cleanup Logging: Always restore original stdout/stderr
    sys.stdout = original_stdout
    sys.stderr = original_stderr
    if 'log' in locals() and log_file:
        log_file.close()
    print("[INFO] Restored standard output/error streams.")
```

```
--- Starting Main Process ---

[Phase 1] Loading dataset from 'food_predictions.csv'…

[Phase 2] Vectorizing dataset…
[INFO] Dataset length: 10020

[Phase 3] Check vectorized data
  Features: <Compressed Sparse Row sparse matrix of dtype 'float64'
        with 13 stored elements and shape (1, 2214)>
  Coords        Values
  (0, 486)      0.18906573466080354
  (0, 1692)     0.36280099125122656
  (0, 656)      0.34251137829537215
  (0, 499)      0.18004423698562447
```

```
  (0, 103)      0.2591121087630078
  (0, 52)       0.10731739598299057
  (0, 2003)     0.25985567632738704
  (0, 106)      0.49475648317838145
  (0, 2162)     0.10547004900525823
  (0, 1742)     0.2961612146933974
  (0, 1338)     0.1997704180635649
  (0, 798)      0.22337156390945978
  (0, 1875)     0.3213970858820761
  Target: 1

[Phase 4a] Splitting data into training and testing sets…
  Training Features shape: (8016, 2214)
  Training Targets shape: (8016,)
  Testing Features shape: (2004, 2214)
  Testing Targets shape: (2004,)

[Phase 4b] Scaling features for kNN…

[Phase 5a] Hyperparameter tuning for Random Forest…
Best Random Forest parameters: {'max_depth': None, 'min_samples_leaf': 4,
'min_samples_split': 10, 'n_estimators': 50}

[Phase 5b] Hyperparameter tuning for K-Nearest Neighbors…
Best kNN parameters: {'metric': 'euclidean', 'n_neighbors': 9, 'weights':
'distance'}

[Phase 6a] Running prediction on Random Forest…

[Phase 6b] Running prediction on K-Nearest Neighbors…

[Phase 7a] Evaluate performance of Random Forest…
Random Forest Accuracy: 0.7455089820359282
              precision    recall  f1-score   support

           0       0.67      0.42      0.52       649
           1       0.76      0.90      0.83      1355

    accuracy                           0.75      2004
   macro avg       0.72      0.66      0.67      2004
weighted avg       0.73      0.75      0.73      2004


[Phase 7b] Evaluate performance of K-Nearest Neighbors…
K-Nearest Neighbor Accuracy: 0.6951097804391217
              precision    recall  f1-score   support

           0       0.54      0.40      0.46       649
```

```
           1       0.75      0.83      0.79      1355

    accuracy                           0.70      2004
   macro avg       0.64      0.62      0.62      2004
weighted avg       0.68      0.70      0.68      2004

[INFO] Restored standard output/error streams.
```

2.9 Function for training the RNN, including hyperparameter tuning

[18]:
```python
def train_rnn(train_loader, val_loader, vocab_size, max_length, tokenizer=None):
    """Trains the RNN model, saves the best model, and evaluates its performance."""

    if tokenizer is None:
        print("[ERROR] Tokenizer not provided to train_rnn function")
        return

    # Create a proper binary classification dataset for the RNN
    from torch.utils.data import TensorDataset, DataLoader
    # Import pytorch lightning's Trainer if not imported at the top
    try:
        from pytorch_lightning import Trainer
    except ImportError:
        print("[ERROR] pytorch_lightning is not installed. Please install it with pip install pytorch-lightning")
        return

    # Extract data from the existing loader and create tensors for binary classification
    train_inputs = []
    train_labels = []
    for batch in train_loader:
        # For binary classification, we'll use the 'contains_allergen' label
        # First ensure inputs are tensors of integers (not strings)
        inputs = batch["input_ids"]  # Shape: [batch_size, seq_len]
        # For simplicity, we'll convert the target based on if "true" appears in the text
        # Make sure to convert each tensor to a list of integers before passing to tokenizer.decode
        labels = torch.tensor([1 if "true" in tokenizer.decode(ids.tolist()).lower() else 0
                               for ids in inputs], dtype=torch.float)

        train_inputs.append(inputs)
        train_labels.append(labels)
```

```
    # Ensure all tensors have the same sequence length before concatenation
    if train_inputs:
        try:
            # Find the minimum sequence length across all batches
            min_seq_len = min(inp.size(1) for inp in train_inputs)

            # Truncate all tensors to the minimum length
            truncated_inputs = [inp[:, :min_seq_len] for inp in train_inputs]

            # Now concatenate the truncated tensors
            all_train_inputs = torch.cat(truncated_inputs, dim=0)
            all_train_labels = torch.cat(train_labels, dim=0)

            # Create new tensor datasets and loaders
            train_dataset = TensorDataset(all_train_inputs, all_train_labels)
            rnn_train_loader = DataLoader(train_dataset, batch_size=32,␣
↪shuffle=True)

            # Do the same for validation
            val_inputs = []
            val_labels = []
            for batch in val_loader:
                inputs = batch["input_ids"]
                # Convert tensors to lists before decoding
                labels = torch.tensor([1 if "true" in tokenizer.decode(x.cpu().
↪tolist()).lower() else 0
                                       for x in inputs], dtype=torch.float)
                val_inputs.append(inputs)
                val_labels.append(labels)

            if val_inputs:
                # Make sure validation tensors also have consistent sequence␣
↪length
                val_min_seq_len = min(inp.size(1) for inp in val_inputs)
                # Use the smaller of train and validation min lengths to ensure␣
↪compatibility
                final_seq_len = min(min_seq_len, val_min_seq_len)

                # Truncate all tensors to the consistent length
                truncated_train_inputs = [inp[:, :final_seq_len] for inp in␣
↪train_inputs]
                all_train_inputs = torch.cat(truncated_train_inputs, dim=0)

                # Truncate all validation tensors to the consistent length
                truncated_val_inputs = [inp[:, :final_seq_len] for inp in␣
↪val_inputs]
```

```
                # Now concatenate the truncated validation tensors
                all_val_inputs = torch.cat(truncated_val_inputs, dim=0)
                all_val_labels = torch.cat(val_labels, dim=0)

                val_dataset = TensorDataset(all_val_inputs, all_val_labels)
                rnn_val_loader = DataLoader(val_dataset, batch_size=32,␣
↪shuffle=False)
            else:
                rnn_val_loader = None
        except Exception as e:
            print(f"[ERROR] Error preparing data for RNN: {e}")
            import traceback
            traceback.print_exc()
            return
    else:
        print("[ERROR] No training data available for RNN")
        return

    device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

    try:
        # Import early stopping callback
        from pytorch_lightning.callbacks import EarlyStopping

        # Create early stopping callback
        early_stop_callback = EarlyStopping(
            monitor='val_loss',
            min_delta=0.00,
            patience=3,
            verbose=True,
            mode='min'
        )

        # Train the final RNN model with the best hyperparameters
        rnn_model = RNNModel(vocab_size, embedding_dim=128, hidden_units=128,␣
↪dropout_rate=0.2, lr=1e-3)

        # Enable mixed precision training for faster computation
        from pytorch_lightning.plugins import MixedPrecisionPlugin

        trainer = Trainer(
            max_epochs=10,
            gpus=1 if torch.cuda.is_available() else 0,
            callbacks=[early_stop_callback],
            precision=16 if torch.cuda.is_available() else 32,  # Use FP16 if␣
↪GPU is available
```

```
            accelerator='gpu' if torch.cuda.is_available() else 'cpu'
        )
        trainer.fit(rnn_model, rnn_train_loader, rnn_val_loader)

        # Save the best RNN model
        torch.save(rnn_model.state_dict(), 'rnn_model.pth')
        print("Best RNN model saved to rnn_model.pth")

        # Evaluate the RNN model
        rnn_model.eval()  # Set to evaluation mode
        all_preds = []
        all_labels = []

        with torch.no_grad():
            for batch in rnn_val_loader:
                x, y = batch
                x = x.to(device)
                y = y.to(device)
                logits = rnn_model(x)  # Use rnn_model instead of best_rnn_model
                preds = torch.round(torch.sigmoid(logits)).squeeze()  # Round␣
↪predictions to 0/1
                all_preds.extend(preds.cpu().tolist())
                all_labels.extend(y.cpu().tolist())

        # Calculate accuracy, precision, recall, and F1-score
        accuracy = accuracy_score(all_labels, all_preds)
        precision = precision_score(all_labels, all_preds)
        recall = recall_score(all_labels, all_preds)
        f1 = f1_score(all_labels, all_preds)

        print(f"RNN Evaluation Metrics:")
        print(f"  Accuracy: {accuracy:.4f}")
        print(f"  Precision: {precision:.4f}")
        print(f"  Recall: {recall:.4f}")
        print(f"  F1-score: {f1:.4f}")

        # Append evaluation metrics to HTML report
        try:
            with open('report.html', 'a') as f:
                f.write('<h2>RNN Evaluation Metrics</h2>\n')
                f.write(f'<p>Accuracy: {accuracy:.4f}</p>\n')
                f.write(f'<p>Precision: {precision:.4f}</p>\n')
                f.write(f'<p>Recall: {recall:.4f}</p>\n')
                f.write(f'<p>F1-score: {f1:.4f}</p>\n')
        except Exception as e:
            print(f"[ERROR] Failed to append RNN metrics to report: {e}")
```

```
    except Exception as e:
        print(f"[ERROR] Error during RNN training: {e}")
        import traceback
        traceback.print_exc()
```

2.10 Function for training the transformer

[19]:
```
def train_transformer(train_loader_func, val_loader_func, vocab_size,␣
↪tokenizer=None):
    """Trains the Transformer model, saves the best model, and evaluates its␣
↪performance."""

    if tokenizer is None:
        print("[ERROR] Tokenizer not provided to train_transformer function")
        return

    # Create and train the Transformer model with default parameters
    print("[INFO] Creating transformer model with default parameters")
    model = DecoderOnlyModelWrapper(
        vocab_size,
        d_model=128,
        nhead=4,
        num_layers=4,
        dim_feedforward=512,
        lr=1e-3
    )
    device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
    model.to(device)

    # Train the model
    print("[INFO] Training transformer model")
    train_losses, val_losses = train_loop(model, train_loader_func,␣
↪val_loader_func,
                                          epochs=20, device=device, patience=5)

    # Save the trained model
    torch.save(model.state_dict(), 'best_transformer_model.pth')
    print("Transformer model saved to best_transformer_model.pth")

    # Evaluate the Transformer model
    print("[INFO] Creating evaluation dataset")
    eval_dataset = FoodDataset(csv_file_path)
    eval_dataset.set_tokenizer(tokenizer)

    try:
        # Add debug information to diagnose dataset issues
        print(f"[DEBUG] Evaluation dataset length: {len(eval_dataset)}")
```

```
        if len(eval_dataset) > 0:
            sample_item = eval_dataset[0]
            print(f"[DEBUG] Sample item from evaluation dataset:␣
↪{type(sample_item)}")
            print(f"[DEBUG] Is sequence? {isinstance(sample_item, (list,␣
↪tuple))}")
            if hasattr(sample_item, "__len__"):
                print(f"[DEBUG] Item length: {len(sample_item)}")

        precision, recall, f1 = compute_metrics(model, eval_dataset, tokenizer,␣
↪device=device, batch_size=8)

        print(f"Transformer Evaluation Metrics:")
        print(f"  Precision: {precision:.4f}")
        print(f"  Recall: {recall:.4f}")
        print(f"  F1-score: {f1:.4f}")

        # Append evaluation metrics to HTML report
        with open('report.html', 'a') as f:
            f.write('<h2>Transformer Evaluation Metrics</h2>\n')
            f.write(f'<p>Precision: {precision:.4f}</p>\n')
            f.write(f'<p>Recall: {recall:.4f}</p>\n')
            f.write(f'<p>F1-score: {f1:.4f}</p>\n')
            f.write('</body></html>')  # Close the HTML tags
    except Exception as e:
        print(f"[ERROR] Failed to compute or append Transformer metrics: {e}")
        import traceback
        traceback.print_exc()
```

2.11 Main Execution

[20]:
```
# --- Main Execution Logic ---

# Define filenames
log_filename = "log.txt"
csv_filename = "food_predictions.csv" # Assumed to be created or exist
report_filename = "report.html"
loss_plot_filename = "training_validation_loss.png"
conf_matrix_filename = "confusion_matrix.png"
model_save_filename = "trained_model.pth"

# Clear log file at the start
try:
    with open(log_filename, "w") as f:
        f.write("--- Log Start ---\n")
    print(f"[INFO] Cleared log file: {log_filename}")
except IOError as e:
```

```
    print(f"[WARN] Could not clear log file {log_filename}: {e}")

# Keep original stdout/stderr
original_stdout = sys.stdout
original_stderr = sys.stderr

# Open log file in append mode and start Tee redirection
try:
    log_file = open(log_filename, "a", encoding='utf-8')
    sys.stdout = Tee(original_stdout, log_file)
    sys.stderr = Tee(original_stderr, log_file)

    print("\n--- Starting Main Process ---")

    # Load Dataset
    print(f"\n[Phase 1] Loading dataset from '{csv_filename}'...")
    # Define dataset parameters
    MAX_SEQ_LEN = 128 # Maximum sequence length for truncation
    dset = FoodDataset(csv_filename, max_len=MAX_SEQ_LEN)

    # Test Dataset Length (early check)
    test_dataset_length(dset)
    if len(dset) == 0:
        raise ValueError("Dataset is empty. Cannot proceed. Check CSV file and␣
↪path.")

    # Initialize and Train Tokenizer
    print("\n[Phase 2] Initializing and training tokenizer...")
    # Get raw text samples for tokenizer training
    texts_for_tokenizer = [dset.samples[i] for i in range(len(dset))]
    tokenizer = BPETokenizer(texts_for_tokenizer)
    vocab_size = tokenizer.vocab_size
    print(f"  Tokenizer vocabulary size: {vocab_size}")

    # Set Tokenizer for Dataset
    dset.set_tokenizer(tokenizer)

    # Split the data into training and validation sets
    train_dataset, val_dataset = torch.utils.data.random_split(dset,␣
↪[int(len(dset) * 0.8), len(dset) - int(len(dset) * 0.8)])

    # Create data loaders with collate_fn that includes the tokenizer
    train_loader = torch.utils.data.DataLoader(train_dataset, batch_size=32,␣
↪shuffle=True,
                                               collate_fn=lambda batch:␣
↪collate_fn(batch, tokenizer))
```

```
    val_loader = torch.utils.data.DataLoader(val_dataset, batch_size=32,␣
 ↪shuffle=False,
                                             collate_fn=lambda batch:␣
 ↪collate_fn(batch, tokenizer))

    # Calculate vocabulary size
    vocab_size = tokenizer.vocab_size

    # Get maximum sequence length
    max_length = max(len(sample) for sample in dset)

    # Define device
    device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
    print(f"Using device: {device}")

    # Train the RNN model
    train_rnn(train_loader, val_loader, vocab_size, max_length, tokenizer)

    # Train the Transformer model
    train_transformer(lambda: train_loader, lambda: val_loader, vocab_size,␣
 ↪tokenizer)  # Pass loader functions

    print("Training and evaluation completed.")

finally:
    # Cleanup Logging: Always restore original stdout/stderr
    sys.stdout = original_stdout
    sys.stderr = original_stderr
    if 'log_file' in locals() and log_file:
        log_file.close()
    print("[INFO] Restored standard output/error streams.")
```

```
[INFO] Cleared log file: log.txt

--- Starting Main Process ---

[Phase 1] Loading dataset from 'food_predictions.csv'…
[INFO] Loaded 10020 samples from food_predictions.csv.
[INFO] Dataset length: 10020

[Phase 2] Initializing and training tokenizer…
[INFO] Trained BPE tokenizer. Vocab size: 5817
  Tokenizer vocabulary size: 5817
[INFO] Tokenizer set for the dataset.
[INFO] Trained BPE tokenizer. Vocab size: 5817
  Tokenizer vocabulary size: 5817
[INFO] Tokenizer set for the dataset.
```

```
Using device: cpu
Using device: cpu

C:\Users\pilchj\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.12_qbz5
n2kfra8p0\LocalCache\local-packages\Python312\site-
packages\pytorch_lightning\trainer\connectors\accelerator_connector.py:478:
LightningDeprecationWarning: Setting `Trainer(gpus=0)` is deprecated in v1.7 and
will be removed in v2.0. Please use `Trainer(accelerator='gpu', devices=0)`
instead.
  rank_zero_deprecation(
GPU available: False, used: False
TPU available: False, using: 0 TPU cores
IPU available: False, using: 0 IPUs
HPU available: False, using: 0 HPUs

  | Name      | Type      | Params
----------------------------------------
0 | embedding | Embedding | 744 K
1 | rnn       | GRU       | 99.1 K
2 | dropout   | Dropout   | 0
3 | fc        | Linear    | 129
----------------------------------------
843 K     Trainable params
0         Non-trainable params
843 K     Total params
3.375     Total estimated model params size (MB)
TPU available: False, using: 0 TPU cores
IPU available: False, using: 0 IPUs
HPU available: False, using: 0 HPUs

  | Name      | Type      | Params
----------------------------------------
0 | embedding | Embedding | 744 K
1 | rnn       | GRU       | 99.1 K
2 | dropout   | Dropout   | 0
3 | fc        | Linear    | 129
----------------------------------------
843 K     Trainable params
0         Non-trainable params
843 K     Total params
3.375     Total estimated model params size (MB)

Sanity Checking: 0it [00:00, ?it/s]

C:\Users\pilchj\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.12_qbz5
n2kfra8p0\LocalCache\local-packages\Python312\site-
packages\pytorch_lightning\trainer\connectors\data_connector.py:224:
PossibleUserWarning: The dataloader, val_dataloader 0, does not have many
workers which may be a bottleneck. Consider increasing the value of the
```

```
`num_workers` argument` (try 16 which is the number of cpus on this machine) in
the `DataLoader` init to improve performance.
  rank_zero_warn(
C:\Users\pilchj\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.12_qbz5
n2kfra8p0\LocalCache\local-packages\Python312\site-
packages\pytorch_lightning\trainer\connectors\data_connector.py:224:
PossibleUserWarning: The dataloader, train_dataloader, does not have many
workers which may be a bottleneck. Consider increasing the value of the
`num_workers` argument` (try 16 which is the number of cpus on this machine) in
the `DataLoader` init to improve performance.
  rank_zero_warn(

Training: 0it [00:00, ?it/s]

Validation: 0it [00:00, ?it/s]

Metric val_loss improved. New best score: 0.105

Validation: 0it [00:00, ?it/s]

Validation: 0it [00:00, ?it/s]

Validation: 0it [00:00, ?it/s]

Monitored metric val_loss did not improve in the last 3 records. Best score:
0.105. Signaling Trainer to stop.

Best RNN model saved to rnn_model.pth
RNN Evaluation Metrics:
  Accuracy: 0.9501
  Precision: 0.9593
  Recall: 0.9665
  F1-score: 0.9629
[INFO] Creating transformer model with default parameters
[INFO] Initialized PyTorch DecoderOnlyModelWrapper.
[INFO] Training transformer model
[INFO] Model moved to cpu. Mixed precision training: False
--- Starting Training --- Epochs: 20, Device: cpu, Patience: 5 ---

=== Epoch 1/20 ===
  Training…
RNN Evaluation Metrics:
  Accuracy: 0.9501
  Precision: 0.9593
  Recall: 0.9665
  F1-score: 0.9629
[INFO] Creating transformer model with default parameters
[INFO] Initialized PyTorch DecoderOnlyModelWrapper.
[INFO] Training transformer model
[INFO] Model moved to cpu. Mixed precision training: False
--- Starting Training --- Epochs: 20, Device: cpu, Patience: 5 ---
```

```
=== Epoch 1/20 ===
  Training…

C:\Users\pilchj\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.12_qbz5
n2kfra8p0\LocalCache\local-packages\Python312\site-
packages\torch\nn\functional.py:5849: UserWarning: Support for mismatched
key_padding_mask and attn_mask is deprecated. Use same type for both instead.
  warnings.warn(

    Step 10: current batch loss = 6.4059
    Step 20: current batch loss = 5.0836
    Step 20: current batch loss = 5.0836
    Step 30: current batch loss = 4.3229
    Step 30: current batch loss = 4.3229
    Step 40: current batch loss = 4.1509
    Step 40: current batch loss = 4.1509
    Step 50: current batch loss = 3.8561
    Step 50: current batch loss = 3.8561
    Step 60: current batch loss = 3.7025
    Step 60: current batch loss = 3.7025
    Step 70: current batch loss = 3.3781
    Step 70: current batch loss = 3.3781
    Step 80: current batch loss = 3.2047
    Step 80: current batch loss = 3.2047
    Step 90: current batch loss = 3.2550
    Step 90: current batch loss = 3.2550
    Step 100: current batch loss = 2.8622
    Step 100: current batch loss = 2.8622
    Step 110: current batch loss = 2.5969
    Step 110: current batch loss = 2.5969
    Step 120: current batch loss = 2.5744
    Step 120: current batch loss = 2.5744
    Step 130: current batch loss = 2.1951
    Step 130: current batch loss = 2.1951
    Step 140: current batch loss = 2.0412
    Step 140: current batch loss = 2.0412
    Step 150: current batch loss = 1.8397
    Step 150: current batch loss = 1.8397
    Step 160: current batch loss = 1.5901
    Step 160: current batch loss = 1.5901
    Step 170: current batch loss = 1.5611
    Step 170: current batch loss = 1.5611
    Step 180: current batch loss = 1.3395
    Step 180: current batch loss = 1.3395
    Step 190: current batch loss = 1.2652
    Step 190: current batch loss = 1.2652
    Step 200: current batch loss = 1.1271
    Step 200: current batch loss = 1.1271
    Step 210: current batch loss = 0.8777
```

```
    Step 210: current batch loss = 0.8777
    Step 220: current batch loss = 1.1604
    Step 220: current batch loss = 1.1604
    Step 230: current batch loss = 1.1469
    Step 230: current batch loss = 1.1469
    Step 240: current batch loss = 0.9147
    Step 240: current batch loss = 0.9147
    Step 250: current batch loss = 0.8150
  Epoch 1 Average Train Loss: 2.6474
  Validating…
    Step 250: current batch loss = 0.8150
  Epoch 1 Average Train Loss: 2.6474
  Validating…
    Validation Step 10: current batch loss = 0.5741
    Validation Step 10: current batch loss = 0.5741
    Validation Step 20: current batch loss = 0.6701
    Validation Step 20: current batch loss = 0.6701
    Validation Step 30: current batch loss = 0.5934
    Validation Step 30: current batch loss = 0.5934
    Validation Step 40: current batch loss = 0.5813
    Validation Step 40: current batch loss = 0.5813
    Validation Step 50: current batch loss = 0.5787
    Validation Step 50: current batch loss = 0.5787
    Validation Step 60: current batch loss = 0.5673
  Epoch 1 Average Validation Loss: 0.6169
    New best validation loss: 0.6169. Patience reset.
    Validation Step 60: current batch loss = 0.5673
  Epoch 1 Average Validation Loss: 0.6169
    New best validation loss: 0.6169. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 2/20 ===
  Training…
    Best model checkpoint saved with additional training state.

=== Epoch 2/20 ===
  Training…
    Step 10: current batch loss = 0.5623
    Step 10: current batch loss = 0.5623
    Step 20: current batch loss = 0.5940
    Step 20: current batch loss = 0.5940
    Step 30: current batch loss = 0.4760
    Step 30: current batch loss = 0.4760
    Step 40: current batch loss = 0.6294
    Step 40: current batch loss = 0.6294
    Step 50: current batch loss = 0.4218
    Step 50: current batch loss = 0.4218
    Step 60: current batch loss = 0.4711
```

```
  Step 60: current batch loss = 0.4711
  Step 70: current batch loss = 0.2654
  Step 70: current batch loss = 0.2654
  Step 80: current batch loss = 0.3540
  Step 80: current batch loss = 0.3540
  Step 90: current batch loss = 0.3036
  Step 90: current batch loss = 0.3036
  Step 100: current batch loss = 0.4132
  Step 100: current batch loss = 0.4132
  Step 110: current batch loss = 0.2307
  Step 110: current batch loss = 0.2307
  Step 120: current batch loss = 0.2779
  Step 120: current batch loss = 0.2779
  Step 130: current batch loss = 0.2726
  Step 130: current batch loss = 0.2726
  Step 140: current batch loss = 0.2575
  Step 140: current batch loss = 0.2575
  Step 150: current batch loss = 0.2520
  Step 150: current batch loss = 0.2520
  Step 160: current batch loss = 0.3606
  Step 160: current batch loss = 0.3606
  Step 170: current batch loss = 0.1393
  Step 170: current batch loss = 0.1393
  Step 180: current batch loss = 0.1730
  Step 180: current batch loss = 0.1730
  Step 190: current batch loss = 0.2753
  Step 190: current batch loss = 0.2753
  Step 200: current batch loss = 0.1851
  Step 200: current batch loss = 0.1851
  Step 210: current batch loss = 0.1162
  Step 210: current batch loss = 0.1162
  Step 220: current batch loss = 0.1442
  Step 220: current batch loss = 0.1442
  Step 230: current batch loss = 0.1252
  Step 230: current batch loss = 0.1252
  Step 240: current batch loss = 0.1428
  Step 240: current batch loss = 0.1428
  Step 250: current batch loss = 0.1770
Epoch 2 Average Train Loss: 0.3299
Validating…
  Step 250: current batch loss = 0.1770
Epoch 2 Average Train Loss: 0.3299
Validating…
  Validation Step 10: current batch loss = 0.1497
  Validation Step 10: current batch loss = 0.1497
  Validation Step 20: current batch loss = 0.1769
  Validation Step 20: current batch loss = 0.1769
  Validation Step 30: current batch loss = 0.1109
```

```
    Validation Step 30: current batch loss = 0.1109
    Validation Step 40: current batch loss = 0.1443
    Validation Step 40: current batch loss = 0.1443
    Validation Step 50: current batch loss = 0.1289
    Validation Step 50: current batch loss = 0.1289
    Validation Step 60: current batch loss = 0.1268
  Epoch 2 Average Validation Loss: 0.1430
    New best validation loss: 0.1430. Patience reset.
    Validation Step 60: current batch loss = 0.1268
  Epoch 2 Average Validation Loss: 0.1430
    New best validation loss: 0.1430. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 3/20 ===
  Training…
    Best model checkpoint saved with additional training state.

=== Epoch 3/20 ===
  Training…
    Step 10: current batch loss = 0.1223
    Step 10: current batch loss = 0.1223
    Step 20: current batch loss = 0.1216
    Step 20: current batch loss = 0.1216
    Step 30: current batch loss = 0.1540
    Step 30: current batch loss = 0.1540
    Step 40: current batch loss = 0.0795
    Step 40: current batch loss = 0.0795
    Step 50: current batch loss = 0.1378
    Step 50: current batch loss = 0.1378
    Step 60: current batch loss = 0.1023
    Step 60: current batch loss = 0.1023
    Step 70: current batch loss = 0.1058
    Step 70: current batch loss = 0.1058
    Step 80: current batch loss = 0.0978
    Step 80: current batch loss = 0.0978
    Step 90: current batch loss = 0.1561
    Step 90: current batch loss = 0.1561
    Step 100: current batch loss = 0.1216
    Step 100: current batch loss = 0.1216
    Step 110: current batch loss = 0.0883
    Step 110: current batch loss = 0.0883
    Step 120: current batch loss = 0.0987
    Step 120: current batch loss = 0.0987
    Step 130: current batch loss = 0.0763
    Step 130: current batch loss = 0.0763
    Step 140: current batch loss = 0.0604
    Step 140: current batch loss = 0.0604
    Step 150: current batch loss = 0.0998
```

```
    Step 150: current batch loss = 0.0998
    Step 160: current batch loss = 0.0916
    Step 160: current batch loss = 0.0916
    Step 170: current batch loss = 0.1043
    Step 170: current batch loss = 0.1043
    Step 180: current batch loss = 0.0807
    Step 180: current batch loss = 0.0807
    Step 190: current batch loss = 0.0413
    Step 190: current batch loss = 0.0413
    Step 200: current batch loss = 0.1405
    Step 200: current batch loss = 0.1405
    Step 210: current batch loss = 0.0542
    Step 210: current batch loss = 0.0542
    Step 220: current batch loss = 0.1048
    Step 220: current batch loss = 0.1048
    Step 230: current batch loss = 0.0857
    Step 230: current batch loss = 0.0857
    Step 240: current batch loss = 0.0561
    Step 240: current batch loss = 0.0561
    Step 250: current batch loss = 0.0887
  Epoch 3 Average Train Loss: 0.0983
  Validating…
    Step 250: current batch loss = 0.0887
  Epoch 3 Average Train Loss: 0.0983
  Validating…
    Validation Step 10: current batch loss = 0.0703
    Validation Step 10: current batch loss = 0.0703
    Validation Step 20: current batch loss = 0.1100
    Validation Step 20: current batch loss = 0.1100
    Validation Step 30: current batch loss = 0.0568
    Validation Step 30: current batch loss = 0.0568
    Validation Step 40: current batch loss = 0.0664
    Validation Step 40: current batch loss = 0.0664
    Validation Step 50: current batch loss = 0.0671
    Validation Step 50: current batch loss = 0.0671
    Validation Step 60: current batch loss = 0.0636
  Epoch 3 Average Validation Loss: 0.0798
    New best validation loss: 0.0798. Patience reset.
    Validation Step 60: current batch loss = 0.0636
  Epoch 3 Average Validation Loss: 0.0798
    New best validation loss: 0.0798. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 4/20 ===
  Training…
    Best model checkpoint saved with additional training state.

=== Epoch 4/20 ===
```

```
Training…
  Step 10: current batch loss = 0.0695
  Step 10: current batch loss = 0.0695
  Step 20: current batch loss = 0.0340
  Step 20: current batch loss = 0.0340
  Step 30: current batch loss = 0.0442
  Step 30: current batch loss = 0.0442
  Step 40: current batch loss = 0.0321
  Step 40: current batch loss = 0.0321
  Step 50: current batch loss = 0.0340
  Step 50: current batch loss = 0.0340
  Step 60: current batch loss = 0.0300
  Step 60: current batch loss = 0.0300
  Step 70: current batch loss = 0.0500
  Step 70: current batch loss = 0.0500
  Step 80: current batch loss = 0.0312
  Step 80: current batch loss = 0.0312
  Step 90: current batch loss = 0.0748
  Step 90: current batch loss = 0.0748
  Step 100: current batch loss = 0.0470
  Step 100: current batch loss = 0.0470
  Step 110: current batch loss = 0.0269
  Step 110: current batch loss = 0.0269
  Step 120: current batch loss = 0.0258
  Step 120: current batch loss = 0.0258
  Step 130: current batch loss = 0.0617
  Step 130: current batch loss = 0.0617
  Step 140: current batch loss = 0.0248
  Step 140: current batch loss = 0.0248
  Step 150: current batch loss = 0.0250
  Step 150: current batch loss = 0.0250
  Step 160: current batch loss = 0.0464
  Step 160: current batch loss = 0.0464
  Step 170: current batch loss = 0.0381
  Step 170: current batch loss = 0.0381
  Step 180: current batch loss = 0.0355
  Step 180: current batch loss = 0.0355
  Step 190: current batch loss = 0.0501
  Step 190: current batch loss = 0.0501
  Step 200: current batch loss = 0.0476
  Step 200: current batch loss = 0.0476
  Step 210: current batch loss = 0.0202
  Step 210: current batch loss = 0.0202
  Step 220: current batch loss = 0.0349
  Step 220: current batch loss = 0.0349
  Step 230: current batch loss = 0.0485
  Step 230: current batch loss = 0.0485
  Step 240: current batch loss = 0.0534
```

```
    Step 240: current batch loss = 0.0534
    Step 250: current batch loss = 0.0352
  Epoch 4 Average Train Loss: 0.0449
  Validating…
    Step 250: current batch loss = 0.0352
  Epoch 4 Average Train Loss: 0.0449
  Validating…
    Validation Step 10: current batch loss = 0.0423
    Validation Step 10: current batch loss = 0.0423
    Validation Step 20: current batch loss = 0.0926
    Validation Step 20: current batch loss = 0.0926
    Validation Step 30: current batch loss = 0.0453
    Validation Step 30: current batch loss = 0.0453
    Validation Step 40: current batch loss = 0.0426
    Validation Step 40: current batch loss = 0.0426
    Validation Step 50: current batch loss = 0.0524
    Validation Step 50: current batch loss = 0.0524
    Validation Step 60: current batch loss = 0.0481
  Epoch 4 Average Validation Loss: 0.0598
    New best validation loss: 0.0598. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 5/20 ===
  Training…
    Validation Step 60: current batch loss = 0.0481
  Epoch 4 Average Validation Loss: 0.0598
    New best validation loss: 0.0598. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 5/20 ===
  Training…
    Step 10: current batch loss = 0.0199
    Step 10: current batch loss = 0.0199
    Step 20: current batch loss = 0.0394
    Step 20: current batch loss = 0.0394
    Step 30: current batch loss = 0.0448
    Step 30: current batch loss = 0.0448
    Step 40: current batch loss = 0.0365
    Step 40: current batch loss = 0.0365
    Step 50: current batch loss = 0.0110
    Step 50: current batch loss = 0.0110
    Step 60: current batch loss = 0.0117
    Step 60: current batch loss = 0.0117
    Step 70: current batch loss = 0.0196
    Step 70: current batch loss = 0.0196
    Step 80: current batch loss = 0.0247
    Step 80: current batch loss = 0.0247
    Step 90: current batch loss = 0.0255
```

```
  Step 90: current batch loss = 0.0255
  Step 100: current batch loss = 0.0261
  Step 100: current batch loss = 0.0261
  Step 110: current batch loss = 0.0242
  Step 110: current batch loss = 0.0242
  Step 120: current batch loss = 0.0406
  Step 120: current batch loss = 0.0406
  Step 130: current batch loss = 0.0201
  Step 130: current batch loss = 0.0201
  Step 140: current batch loss = 0.0105
  Step 140: current batch loss = 0.0105
  Step 150: current batch loss = 0.0138
  Step 150: current batch loss = 0.0138
  Step 160: current batch loss = 0.0192
  Step 160: current batch loss = 0.0192
  Step 170: current batch loss = 0.0242
  Step 170: current batch loss = 0.0242
  Step 180: current batch loss = 0.0376
  Step 180: current batch loss = 0.0376
  Step 190: current batch loss = 0.0254
  Step 190: current batch loss = 0.0254
  Step 200: current batch loss = 0.0247
  Step 200: current batch loss = 0.0247
  Step 210: current batch loss = 0.0208
  Step 210: current batch loss = 0.0208
  Step 220: current batch loss = 0.0123
  Step 220: current batch loss = 0.0123
  Step 230: current batch loss = 0.0194
  Step 230: current batch loss = 0.0194
  Step 240: current batch loss = 0.0115
  Step 240: current batch loss = 0.0115
  Step 250: current batch loss = 0.0082
Epoch 5 Average Train Loss: 0.0229
Validating…
  Step 250: current batch loss = 0.0082
Epoch 5 Average Train Loss: 0.0229
Validating…
  Validation Step 10: current batch loss = 0.0273
  Validation Step 10: current batch loss = 0.0273
  Validation Step 20: current batch loss = 0.0891
  Validation Step 20: current batch loss = 0.0891
  Validation Step 30: current batch loss = 0.0395
  Validation Step 30: current batch loss = 0.0395
  Validation Step 40: current batch loss = 0.0411
  Validation Step 40: current batch loss = 0.0411
  Validation Step 50: current batch loss = 0.0470
  Validation Step 50: current batch loss = 0.0470
  Validation Step 60: current batch loss = 0.0443
```

```
  Epoch 5 Average Validation Loss: 0.0521
    New best validation loss: 0.0521. Patience reset.
    Validation Step 60: current batch loss = 0.0443
  Epoch 5 Average Validation Loss: 0.0521
    New best validation loss: 0.0521. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 6/20 ===
  Training…
    Best model checkpoint saved with additional training state.

=== Epoch 6/20 ===
  Training…
    Step 10: current batch loss = 0.0100
    Step 10: current batch loss = 0.0100
    Step 20: current batch loss = 0.0051
    Step 20: current batch loss = 0.0051
    Step 30: current batch loss = 0.0133
    Step 30: current batch loss = 0.0133
    Step 40: current batch loss = 0.0058
    Step 40: current batch loss = 0.0058
    Step 50: current batch loss = 0.0037
    Step 50: current batch loss = 0.0037
    Step 60: current batch loss = 0.0187
    Step 60: current batch loss = 0.0187
    Step 70: current batch loss = 0.0087
    Step 70: current batch loss = 0.0087
    Step 80: current batch loss = 0.0176
    Step 80: current batch loss = 0.0176
    Step 90: current batch loss = 0.0079
    Step 90: current batch loss = 0.0079
    Step 100: current batch loss = 0.0086
    Step 100: current batch loss = 0.0086
    Step 110: current batch loss = 0.0145
    Step 110: current batch loss = 0.0145
    Step 120: current batch loss = 0.0112
    Step 120: current batch loss = 0.0112
    Step 130: current batch loss = 0.0153
    Step 130: current batch loss = 0.0153
    Step 140: current batch loss = 0.0085
    Step 140: current batch loss = 0.0085
    Step 150: current batch loss = 0.0093
    Step 150: current batch loss = 0.0093
    Step 160: current batch loss = 0.0106
    Step 160: current batch loss = 0.0106
    Step 170: current batch loss = 0.0160
    Step 170: current batch loss = 0.0160
    Step 180: current batch loss = 0.0106
```

```
    Step 180: current batch loss = 0.0106
    Step 190: current batch loss = 0.0107
    Step 190: current batch loss = 0.0107
    Step 200: current batch loss = 0.0117
    Step 200: current batch loss = 0.0117
    Step 210: current batch loss = 0.0065
    Step 210: current batch loss = 0.0065
    Step 220: current batch loss = 0.0077
    Step 220: current batch loss = 0.0077
    Step 230: current batch loss = 0.0183
    Step 230: current batch loss = 0.0183
    Step 240: current batch loss = 0.0052
    Step 240: current batch loss = 0.0052
    Step 250: current batch loss = 0.0196
  Epoch 6 Average Train Loss: 0.0119
  Validating…
    Step 250: current batch loss = 0.0196
  Epoch 6 Average Train Loss: 0.0119
  Validating…
    Validation Step 10: current batch loss = 0.0171
    Validation Step 10: current batch loss = 0.0171
    Validation Step 20: current batch loss = 0.0812
    Validation Step 20: current batch loss = 0.0812
    Validation Step 30: current batch loss = 0.0339
    Validation Step 30: current batch loss = 0.0339
    Validation Step 40: current batch loss = 0.0241
    Validation Step 40: current batch loss = 0.0241
    Validation Step 50: current batch loss = 0.0453
    Validation Step 50: current batch loss = 0.0453
    Validation Step 60: current batch loss = 0.0407
  Epoch 6 Average Validation Loss: 0.0454
    New best validation loss: 0.0454. Patience reset.
    Validation Step 60: current batch loss = 0.0407
  Epoch 6 Average Validation Loss: 0.0454
    New best validation loss: 0.0454. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 7/20 ===
  Training…
    Best model checkpoint saved with additional training state.

=== Epoch 7/20 ===
  Training…
    Step 10: current batch loss = 0.0101
    Step 10: current batch loss = 0.0101
    Step 20: current batch loss = 0.0071
    Step 20: current batch loss = 0.0071
    Step 30: current batch loss = 0.0047
```

```
  Step 30: current batch loss = 0.0047
  Step 40: current batch loss = 0.0024
  Step 40: current batch loss = 0.0024
  Step 50: current batch loss = 0.0063
  Step 50: current batch loss = 0.0063
  Step 60: current batch loss = 0.0025
  Step 60: current batch loss = 0.0025
  Step 70: current batch loss = 0.0096
  Step 70: current batch loss = 0.0096
  Step 80: current batch loss = 0.0080
  Step 80: current batch loss = 0.0080
  Step 90: current batch loss = 0.0162
  Step 90: current batch loss = 0.0162
  Step 100: current batch loss = 0.0100
  Step 100: current batch loss = 0.0100
  Step 110: current batch loss = 0.0065
  Step 110: current batch loss = 0.0065
  Step 120: current batch loss = 0.0078
  Step 120: current batch loss = 0.0078
  Step 130: current batch loss = 0.0043
  Step 130: current batch loss = 0.0043
  Step 140: current batch loss = 0.0179
  Step 140: current batch loss = 0.0179
  Step 150: current batch loss = 0.0178
  Step 150: current batch loss = 0.0178
  Step 160: current batch loss = 0.0053
  Step 160: current batch loss = 0.0053
  Step 170: current batch loss = 0.0043
  Step 170: current batch loss = 0.0043
  Step 180: current batch loss = 0.0060
  Step 180: current batch loss = 0.0060
  Step 190: current batch loss = 0.0051
  Step 190: current batch loss = 0.0051
  Step 200: current batch loss = 0.0397
  Step 200: current batch loss = 0.0397
  Step 210: current batch loss = 0.0240
  Step 210: current batch loss = 0.0240
  Step 220: current batch loss = 0.0202
  Step 220: current batch loss = 0.0202
  Step 230: current batch loss = 0.0091
  Step 230: current batch loss = 0.0091
  Step 240: current batch loss = 0.0053
  Step 240: current batch loss = 0.0053
  Step 250: current batch loss = 0.0052
Epoch 7 Average Train Loss: 0.0090
Validating…
  Step 250: current batch loss = 0.0052
Epoch 7 Average Train Loss: 0.0090
```

```
  Validating…
    Validation Step 10: current batch loss = 0.0144
    Validation Step 10: current batch loss = 0.0144
    Validation Step 20: current batch loss = 0.0845
    Validation Step 20: current batch loss = 0.0845
    Validation Step 30: current batch loss = 0.0334
    Validation Step 30: current batch loss = 0.0334
    Validation Step 40: current batch loss = 0.0240
    Validation Step 40: current batch loss = 0.0240
    Validation Step 50: current batch loss = 0.0449
    Validation Step 50: current batch loss = 0.0449
    Validation Step 60: current batch loss = 0.0421
  Epoch 7 Average Validation Loss: 0.0468
    Validation loss did not improve. Current: 0.0468, Best: 0.0454, Delta:
-0.001332
    Early stopping patience: 1/5

=== Epoch 8/20 ===
  Training…
    Validation Step 60: current batch loss = 0.0421
  Epoch 7 Average Validation Loss: 0.0468
    Validation loss did not improve. Current: 0.0468, Best: 0.0454, Delta:
-0.001332
    Early stopping patience: 1/5

=== Epoch 8/20 ===
  Training…
    Step 10: current batch loss = 0.0074
    Step 10: current batch loss = 0.0074
    Step 20: current batch loss = 0.0041
    Step 20: current batch loss = 0.0041
    Step 30: current batch loss = 0.0040
    Step 30: current batch loss = 0.0040
    Step 40: current batch loss = 0.0130
    Step 40: current batch loss = 0.0130
    Step 50: current batch loss = 0.0049
    Step 50: current batch loss = 0.0049
    Step 60: current batch loss = 0.0086
    Step 60: current batch loss = 0.0086
    Step 70: current batch loss = 0.0039
    Step 70: current batch loss = 0.0039
    Step 80: current batch loss = 0.0085
    Step 80: current batch loss = 0.0085
    Step 90: current batch loss = 0.0059
    Step 90: current batch loss = 0.0059
    Step 100: current batch loss = 0.0095
    Step 100: current batch loss = 0.0095
    Step 110: current batch loss = 0.0039
```

```
  Step 110: current batch loss = 0.0039
  Step 120: current batch loss = 0.0076
  Step 120: current batch loss = 0.0076
  Step 130: current batch loss = 0.0076
  Step 130: current batch loss = 0.0076
  Step 140: current batch loss = 0.0121
  Step 140: current batch loss = 0.0121
  Step 150: current batch loss = 0.0163
  Step 150: current batch loss = 0.0163
  Step 160: current batch loss = 0.0064
  Step 160: current batch loss = 0.0064
  Step 170: current batch loss = 0.0037
  Step 170: current batch loss = 0.0037
  Step 180: current batch loss = 0.0046
  Step 180: current batch loss = 0.0046
  Step 190: current batch loss = 0.0054
  Step 190: current batch loss = 0.0054
  Step 200: current batch loss = 0.0026
  Step 200: current batch loss = 0.0026
  Step 210: current batch loss = 0.0034
  Step 210: current batch loss = 0.0034
  Step 220: current batch loss = 0.0031
  Step 220: current batch loss = 0.0031
  Step 230: current batch loss = 0.0027
  Step 230: current batch loss = 0.0027
  Step 240: current batch loss = 0.0015
  Step 240: current batch loss = 0.0015
  Step 250: current batch loss = 0.0025
Epoch 8 Average Train Loss: 0.0072
Validating…
  Step 250: current batch loss = 0.0025
Epoch 8 Average Train Loss: 0.0072
Validating…
  Validation Step 10: current batch loss = 0.0118
  Validation Step 10: current batch loss = 0.0118
  Validation Step 20: current batch loss = 0.0828
  Validation Step 20: current batch loss = 0.0828
  Validation Step 30: current batch loss = 0.0322
  Validation Step 30: current batch loss = 0.0322
  Validation Step 40: current batch loss = 0.0224
  Validation Step 40: current batch loss = 0.0224
  Validation Step 50: current batch loss = 0.0430
  Validation Step 50: current batch loss = 0.0430
  Validation Step 60: current batch loss = 0.0410
  Validation Step 60: current batch loss = 0.0410
Epoch 8 Average Validation Loss: 0.0423
  New best validation loss: 0.0423. Patience reset.
  Best model checkpoint saved with additional training state.
```

```
=== Epoch 9/20 ===
  Training…
  Epoch 8 Average Validation Loss: 0.0423
    New best validation loss: 0.0423. Patience reset.
    Best model checkpoint saved with additional training state.

=== Epoch 9/20 ===
  Training…
    Step 10: current batch loss = 0.0087
    Step 10: current batch loss = 0.0087
    Step 20: current batch loss = 0.0018
    Step 20: current batch loss = 0.0018
    Step 30: current batch loss = 0.0047
    Step 30: current batch loss = 0.0047
    Step 40: current batch loss = 0.0025
    Step 40: current batch loss = 0.0025
    Step 50: current batch loss = 0.0025
    Step 50: current batch loss = 0.0025
    Step 60: current batch loss = 0.0316
    Step 60: current batch loss = 0.0316
    Step 70: current batch loss = 0.0022
    Step 70: current batch loss = 0.0022
    Step 80: current batch loss = 0.0032
    Step 80: current batch loss = 0.0032
    Step 90: current batch loss = 0.0021
    Step 90: current batch loss = 0.0021
    Step 100: current batch loss = 0.0024
    Step 100: current batch loss = 0.0024
    Step 110: current batch loss = 0.0020
    Step 110: current batch loss = 0.0020
    Step 120: current batch loss = 0.0042
    Step 120: current batch loss = 0.0042
    Step 130: current batch loss = 0.0035
    Step 130: current batch loss = 0.0035
    Step 140: current batch loss = 0.0022
    Step 140: current batch loss = 0.0022
    Step 150: current batch loss = 0.0037
    Step 150: current batch loss = 0.0037
    Step 160: current batch loss = 0.0032
    Step 160: current batch loss = 0.0032
    Step 170: current batch loss = 0.0039
    Step 170: current batch loss = 0.0039
    Step 180: current batch loss = 0.0027
    Step 180: current batch loss = 0.0027
    Step 190: current batch loss = 0.0055
    Step 190: current batch loss = 0.0055
    Step 200: current batch loss = 0.0022
```

```
    Step 200: current batch loss = 0.0022
    Step 210: current batch loss = 0.0023
    Step 210: current batch loss = 0.0023
    Step 220: current batch loss = 0.0027
    Step 220: current batch loss = 0.0027
    Step 230: current batch loss = 0.0095
    Step 230: current batch loss = 0.0095
    Step 240: current batch loss = 0.0016
    Step 240: current batch loss = 0.0016
    Step 250: current batch loss = 0.0018
  Epoch 9 Average Train Loss: 0.0044
  Validating…
    Step 250: current batch loss = 0.0018
  Epoch 9 Average Train Loss: 0.0044
  Validating…
    Validation Step 10: current batch loss = 0.0117
    Validation Step 10: current batch loss = 0.0117
    Validation Step 20: current batch loss = 0.0839
    Validation Step 20: current batch loss = 0.0839
    Validation Step 30: current batch loss = 0.0336
    Validation Step 30: current batch loss = 0.0336
    Validation Step 40: current batch loss = 0.0233
    Validation Step 40: current batch loss = 0.0233
    Validation Step 50: current batch loss = 0.0458
    Validation Step 50: current batch loss = 0.0458
    Validation Step 60: current batch loss = 0.0428
    Validation Step 60: current batch loss = 0.0428
  Epoch 9 Average Validation Loss: 0.0441
    Validation loss did not improve. Current: 0.0441, Best: 0.0423, Delta:
-0.001788
    Early stopping patience: 1/5

=== Epoch 10/20 ===
  Training…
  Epoch 9 Average Validation Loss: 0.0441
    Validation loss did not improve. Current: 0.0441, Best: 0.0423, Delta:
-0.001788
    Early stopping patience: 1/5

=== Epoch 10/20 ===
  Training…
    Step 10: current batch loss = 0.0012
    Step 10: current batch loss = 0.0012
    Step 20: current batch loss = 0.0023
    Step 20: current batch loss = 0.0023
    Step 30: current batch loss = 0.0070
    Step 30: current batch loss = 0.0070
    Step 40: current batch loss = 0.0017
```

```
  Step 40: current batch loss = 0.0017
  Step 50: current batch loss = 0.0010
  Step 50: current batch loss = 0.0010
  Step 60: current batch loss = 0.0103
  Step 60: current batch loss = 0.0103
  Step 70: current batch loss = 0.0016
  Step 70: current batch loss = 0.0016
  Step 80: current batch loss = 0.0022
  Step 80: current batch loss = 0.0022
  Step 90: current batch loss = 0.0017
  Step 90: current batch loss = 0.0017
  Step 100: current batch loss = 0.0013
  Step 100: current batch loss = 0.0013
  Step 110: current batch loss = 0.0010
  Step 110: current batch loss = 0.0010
  Step 120: current batch loss = 0.0012
  Step 120: current batch loss = 0.0012
  Step 130: current batch loss = 0.0013
  Step 130: current batch loss = 0.0013
  Step 140: current batch loss = 0.0011
  Step 140: current batch loss = 0.0011
  Step 150: current batch loss = 0.0022
  Step 150: current batch loss = 0.0022
  Step 160: current batch loss = 0.0008
  Step 160: current batch loss = 0.0008
  Step 170: current batch loss = 0.0027
  Step 170: current batch loss = 0.0027
  Step 180: current batch loss = 0.0017
  Step 180: current batch loss = 0.0017
  Step 190: current batch loss = 0.0012
  Step 190: current batch loss = 0.0012
  Step 200: current batch loss = 0.0040
  Step 200: current batch loss = 0.0040
  Step 210: current batch loss = 0.0020
  Step 210: current batch loss = 0.0020
  Step 220: current batch loss = 0.0016
  Step 220: current batch loss = 0.0016
  Step 230: current batch loss = 0.0026
  Step 230: current batch loss = 0.0026
  Step 240: current batch loss = 0.0017
  Step 240: current batch loss = 0.0017
  Step 250: current batch loss = 0.0041
Epoch 10 Average Train Loss: 0.0025
Validating…
  Step 250: current batch loss = 0.0041
Epoch 10 Average Train Loss: 0.0025
Validating…
  Validation Step 10: current batch loss = 0.0136
```

```
    Validation Step 10: current batch loss = 0.0136
    Validation Step 20: current batch loss = 0.0865
    Validation Step 20: current batch loss = 0.0865
    Validation Step 30: current batch loss = 0.0340
    Validation Step 30: current batch loss = 0.0340
    Validation Step 40: current batch loss = 0.0241
    Validation Step 40: current batch loss = 0.0241
    Validation Step 50: current batch loss = 0.0518
    Validation Step 50: current batch loss = 0.0518
    Validation Step 60: current batch loss = 0.0439
  Epoch 10 Average Validation Loss: 0.0443
    Validation loss did not improve. Current: 0.0443, Best: 0.0423, Delta:
-0.002032
    Early stopping patience: 2/5

=== Epoch 11/20 ===
  Training…
    Validation Step 60: current batch loss = 0.0439
  Epoch 10 Average Validation Loss: 0.0443
    Validation loss did not improve. Current: 0.0443, Best: 0.0423, Delta:
-0.002032
    Early stopping patience: 2/5

=== Epoch 11/20 ===
  Training…
    Step 10: current batch loss = 0.0026
    Step 10: current batch loss = 0.0026
    Step 20: current batch loss = 0.0020
    Step 20: current batch loss = 0.0020
    Step 30: current batch loss = 0.0026
    Step 30: current batch loss = 0.0026
    Step 40: current batch loss = 0.0012
    Step 40: current batch loss = 0.0012
    Step 50: current batch loss = 0.0020
    Step 50: current batch loss = 0.0020
    Step 60: current batch loss = 0.0016
    Step 60: current batch loss = 0.0016
    Step 70: current batch loss = 0.0017
    Step 70: current batch loss = 0.0017
    Step 80: current batch loss = 0.0026
    Step 80: current batch loss = 0.0026
    Step 90: current batch loss = 0.0016
    Step 90: current batch loss = 0.0016
    Step 100: current batch loss = 0.0046
    Step 100: current batch loss = 0.0046
    Step 110: current batch loss = 0.0050
    Step 110: current batch loss = 0.0050
    Step 120: current batch loss = 0.0026
```

```
    Step 120: current batch loss = 0.0026
    Step 130: current batch loss = 0.0024
    Step 130: current batch loss = 0.0024
    Step 140: current batch loss = 0.0102
    Step 140: current batch loss = 0.0102
    Step 150: current batch loss = 0.0018
    Step 150: current batch loss = 0.0018
    Step 160: current batch loss = 0.0022
    Step 160: current batch loss = 0.0022
    Step 170: current batch loss = 0.0060
    Step 170: current batch loss = 0.0060
    Step 180: current batch loss = 0.0019
    Step 180: current batch loss = 0.0019
    Step 190: current batch loss = 0.0108
    Step 190: current batch loss = 0.0108
    Step 200: current batch loss = 0.0041
    Step 200: current batch loss = 0.0041
    Step 210: current batch loss = 0.0124
    Step 210: current batch loss = 0.0124
    Step 220: current batch loss = 0.0188
    Step 220: current batch loss = 0.0188
    Step 230: current batch loss = 0.0208
    Step 230: current batch loss = 0.0208
    Step 240: current batch loss = 0.0022
    Step 240: current batch loss = 0.0022
    Step 250: current batch loss = 0.0027
    Step 250: current batch loss = 0.0027
  Epoch 11 Average Train Loss: 0.0045
  Validating…
  Epoch 11 Average Train Loss: 0.0045
  Validating…
    Validation Step 10: current batch loss = 0.0111
    Validation Step 10: current batch loss = 0.0111
    Validation Step 20: current batch loss = 0.0835
    Validation Step 20: current batch loss = 0.0835
    Validation Step 30: current batch loss = 0.0356
    Validation Step 30: current batch loss = 0.0356
    Validation Step 40: current batch loss = 0.0227
    Validation Step 40: current batch loss = 0.0227
    Validation Step 50: current batch loss = 0.0473
    Validation Step 50: current batch loss = 0.0473
    Validation Step 60: current batch loss = 0.0425
  Epoch 11 Average Validation Loss: 0.0460
    Validation loss did not improve. Current: 0.0460, Best: 0.0423, Delta:
-0.003732
    Early stopping patience: 3/5

=== Epoch 12/20 ===
```

```
  Training…
    Validation Step 60: current batch loss = 0.0425
  Epoch 11 Average Validation Loss: 0.0460
    Validation loss did not improve. Current: 0.0460, Best: 0.0423, Delta:
-0.003732
    Early stopping patience: 3/5

=== Epoch 12/20 ===
  Training…
    Step 10: current batch loss = 0.0055
    Step 10: current batch loss = 0.0055
    Step 20: current batch loss = 0.0242
    Step 20: current batch loss = 0.0242
    Step 30: current batch loss = 0.0020
    Step 30: current batch loss = 0.0020
    Step 40: current batch loss = 0.0026
    Step 40: current batch loss = 0.0026
    Step 50: current batch loss = 0.0014
    Step 50: current batch loss = 0.0014
    Step 60: current batch loss = 0.0017
    Step 60: current batch loss = 0.0017
    Step 70: current batch loss = 0.0026
    Step 70: current batch loss = 0.0026
    Step 80: current batch loss = 0.0067
    Step 80: current batch loss = 0.0067
    Step 90: current batch loss = 0.0020
    Step 90: current batch loss = 0.0020
    Step 100: current batch loss = 0.0011
    Step 100: current batch loss = 0.0011
    Step 110: current batch loss = 0.0056
    Step 110: current batch loss = 0.0056
    Step 120: current batch loss = 0.0009
    Step 120: current batch loss = 0.0009
    Step 130: current batch loss = 0.0012
    Step 130: current batch loss = 0.0012
    Step 140: current batch loss = 0.0021
    Step 140: current batch loss = 0.0021
    Step 150: current batch loss = 0.0026
    Step 150: current batch loss = 0.0026
    Step 160: current batch loss = 0.0080
    Step 160: current batch loss = 0.0080
    Step 170: current batch loss = 0.0038
    Step 170: current batch loss = 0.0038
    Step 180: current batch loss = 0.0243
    Step 180: current batch loss = 0.0243
    Step 190: current batch loss = 0.0018
    Step 190: current batch loss = 0.0018
    Step 200: current batch loss = 0.0044
```

```
    Step 200: current batch loss = 0.0044
    Step 210: current batch loss = 0.0033
    Step 210: current batch loss = 0.0033
    Step 220: current batch loss = 0.0075
    Step 220: current batch loss = 0.0075
    Step 230: current batch loss = 0.0141
    Step 230: current batch loss = 0.0141
    Step 240: current batch loss = 0.0188
    Step 240: current batch loss = 0.0188
    Step 250: current batch loss = 0.0167
  Epoch 12 Average Train Loss: 0.0053
  Validating…
    Step 250: current batch loss = 0.0167
  Epoch 12 Average Train Loss: 0.0053
  Validating…
    Validation Step 10: current batch loss = 0.0128
    Validation Step 10: current batch loss = 0.0128
    Validation Step 20: current batch loss = 0.0886
    Validation Step 20: current batch loss = 0.0886
    Validation Step 30: current batch loss = 0.0339
    Validation Step 30: current batch loss = 0.0339
    Validation Step 40: current batch loss = 0.0249
    Validation Step 40: current batch loss = 0.0249
    Validation Step 50: current batch loss = 0.0494
    Validation Step 50: current batch loss = 0.0494
    Validation Step 60: current batch loss = 0.0455
  Epoch 12 Average Validation Loss: 0.0470
    Validation loss did not improve. Current: 0.0470, Best: 0.0423, Delta:
-0.004722
    Early stopping patience: 4/5

=== Epoch 13/20 ===
  Training…
    Validation Step 60: current batch loss = 0.0455
  Epoch 12 Average Validation Loss: 0.0470
    Validation loss did not improve. Current: 0.0470, Best: 0.0423, Delta:
-0.004722
    Early stopping patience: 4/5

=== Epoch 13/20 ===
  Training…
    Step 10: current batch loss = 0.0025
    Step 10: current batch loss = 0.0025
    Step 20: current batch loss = 0.0028
    Step 20: current batch loss = 0.0028
    Step 30: current batch loss = 0.0039
    Step 30: current batch loss = 0.0039
    Step 40: current batch loss = 0.0044
```

```
  Step 40: current batch loss = 0.0044
  Step 50: current batch loss = 0.0040
  Step 50: current batch loss = 0.0040
  Step 60: current batch loss = 0.0047
  Step 60: current batch loss = 0.0047
  Step 70: current batch loss = 0.0059
  Step 70: current batch loss = 0.0059
  Step 80: current batch loss = 0.0021
  Step 80: current batch loss = 0.0021
  Step 90: current batch loss = 0.0467
  Step 90: current batch loss = 0.0467
  Step 100: current batch loss = 0.0038
  Step 100: current batch loss = 0.0038
  Step 110: current batch loss = 0.0023
  Step 110: current batch loss = 0.0023
  Step 120: current batch loss = 0.0032
  Step 120: current batch loss = 0.0032
  Step 130: current batch loss = 0.0040
  Step 130: current batch loss = 0.0040
  Step 140: current batch loss = 0.0110
  Step 140: current batch loss = 0.0110
  Step 150: current batch loss = 0.0048
  Step 150: current batch loss = 0.0048
  Step 160: current batch loss = 0.0033
  Step 160: current batch loss = 0.0033
  Step 170: current batch loss = 0.0037
  Step 170: current batch loss = 0.0037
  Step 180: current batch loss = 0.0028
  Step 180: current batch loss = 0.0028
  Step 190: current batch loss = 0.0093
  Step 190: current batch loss = 0.0093
  Step 200: current batch loss = 0.0030
  Step 200: current batch loss = 0.0030
  Step 210: current batch loss = 0.0211
  Step 210: current batch loss = 0.0211
  Step 220: current batch loss = 0.0125
  Step 220: current batch loss = 0.0125
  Step 230: current batch loss = 0.0014
  Step 230: current batch loss = 0.0014
  Step 240: current batch loss = 0.0025
  Step 240: current batch loss = 0.0025
  Step 250: current batch loss = 0.0223
Epoch 13 Average Train Loss: 0.0069
Validating…
  Step 250: current batch loss = 0.0223
Epoch 13 Average Train Loss: 0.0069
Validating…
  Validation Step 10: current batch loss = 0.0177
```

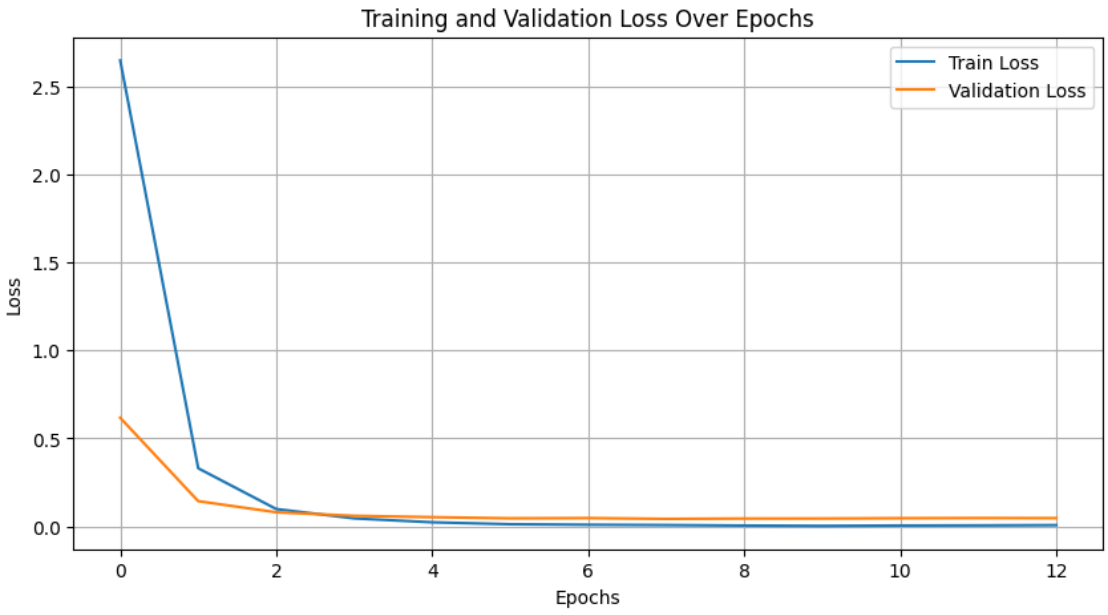
```
    Validation Step 10: current batch loss = 0.0177
    Validation Step 20: current batch loss = 0.0898
    Validation Step 20: current batch loss = 0.0898
    Validation Step 30: current batch loss = 0.0349
    Validation Step 30: current batch loss = 0.0349
    Validation Step 40: current batch loss = 0.0248
    Validation Step 40: current batch loss = 0.0248
    Validation Step 50: current batch loss = 0.0460
    Validation Step 50: current batch loss = 0.0460
    Validation Step 60: current batch loss = 0.0459
  Epoch 13 Average Validation Loss: 0.0465
    Validation loss did not improve. Current: 0.0465, Best: 0.0423, Delta:
-0.004213
    Early stopping patience: 5/5

--- Early Stopping triggered at epoch 13 ---
--- Best validation loss: 0.0423 achieved at epoch 8 ---

--- Training Finished ---
    Validation Step 60: current batch loss = 0.0459
  Epoch 13 Average Validation Loss: 0.0465
    Validation loss did not improve. Current: 0.0465, Best: 0.0423, Delta:
-0.004213
    Early stopping patience: 5/5

--- Early Stopping triggered at epoch 13 ---
--- Best validation loss: 0.0423 achieved at epoch 8 ---

--- Training Finished ---
```



```
[INFO] Loss plot saved as 'training_validation_loss.png'
[INFO] Basic HTML report started in 'report.html'
Transformer model saved to best_transformer_model.pth
[INFO] Creating evaluation dataset
[INFO] Loaded 10020 samples from food_predictions.csv.
[INFO] Tokenizer set for the dataset.
[DEBUG] Evaluation dataset length: 10020
[DEBUG] Sample item from evaluation dataset: <class 'list'>
[DEBUG] Is sequence? True
[DEBUG] Item length: 39
--- Computing Metrics (Precision, Recall, F1) ---
  Processed batch. Total tokens considered so far: 331
  Processed batch. Total tokens considered so far: 638
  Processed batch. Total tokens considered so far: 928
  Processed batch. Total tokens considered so far: 1238
  Processed batch. Total tokens considered so far: 1535
  Processed batch. Total tokens considered so far: 1852
  Processed batch. Total tokens considered so far: 2182
  Processed batch. Total tokens considered so far: 2489
  Processed batch. Total tokens considered so far: 2782
  Processed batch. Total tokens considered so far: 3077
  Processed batch. Total tokens considered so far: 3402
  Processed batch. Total tokens considered so far: 3707
  Processed batch. Total tokens considered so far: 4009
  Processed batch. Total tokens considered so far: 4338
  Processed batch. Total tokens considered so far: 4643
  Processed batch. Total tokens considered so far: 4978
  Processed batch. Total tokens considered so far: 5307
  Processed batch. Total tokens considered so far: 5633
  Processed batch. Total tokens considered so far: 5949
  Processed batch. Total tokens considered so far: 6305
  Processed batch. Total tokens considered so far: 6674
  Processed batch. Total tokens considered so far: 7050
  Processed batch. Total tokens considered so far: 7406
  Processed batch. Total tokens considered so far: 7743
  Processed batch. Total tokens considered so far: 8049
  Processed batch. Total tokens considered so far: 8334
  Processed batch. Total tokens considered so far: 8593
  Processed batch. Total tokens considered so far: 8868
  Processed batch. Total tokens considered so far: 9120
  Processed batch. Total tokens considered so far: 9389
  Processed batch. Total tokens considered so far: 9654
  Processed batch. Total tokens considered so far: 9920
  Processed batch. Total tokens considered so far: 10189
  Processed batch. Total tokens considered so far: 10453
```

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Processed batch. Total tokens considered so far: 10737
Processed batch. Total tokens considered so far: 11022
Processed batch. Total tokens considered so far: 11336
Processed batch. Total tokens considered so far: 11633
Processed batch. Total tokens considered so far: 11919
Processed batch. Total tokens considered so far: 12238
Processed batch. Total tokens considered so far: 12529
Processed batch. Total tokens considered so far: 12813
Processed batch. Total tokens considered so far: 13072
Processed batch. Total tokens considered so far: 13341
Processed batch. Total tokens considered so far: 13594
Processed batch. Total tokens considered so far: 13837
Processed batch. Total tokens considered so far: 14086
Processed batch. Total tokens considered so far: 14330
Processed batch. Total tokens considered so far: 14582
Processed batch. Total tokens considered so far: 14835
Processed batch. Total tokens considered so far: 15089
Processed batch. Total tokens considered so far: 15346
Processed batch. Total tokens considered so far: 15600
Processed batch. Total tokens considered so far: 15860
Processed batch. Total tokens considered so far: 16122
Processed batch. Total tokens considered so far: 16382
Processed batch. Total tokens considered so far: 16649
Processed batch. Total tokens considered so far: 16900
Processed batch. Total tokens considered so far: 17161
Processed batch. Total tokens considered so far: 17421
Processed batch. Total tokens considered so far: 17673
Processed batch. Total tokens considered so far: 17936
Processed batch. Total tokens considered so far: 18224
Processed batch. Total tokens considered so far: 18490
Processed batch. Total tokens considered so far: 18766
Processed batch. Total tokens considered so far: 19051
Processed batch. Total tokens considered so far: 19294
Processed batch. Total tokens considered so far: 19536
Processed batch. Total tokens considered so far: 19784
Processed batch. Total tokens considered so far: 20049
Processed batch. Total tokens considered so far: 20268
Processed batch. Total tokens considered so far: 20523
Processed batch. Total tokens considered so far: 20773
Processed batch. Total tokens considered so far: 21041
Processed batch. Total tokens considered so far: 21294
Processed batch. Total tokens considered so far: 21546
Processed batch. Total tokens considered so far: 21808
Processed batch. Total tokens considered so far: 22083
Processed batch. Total tokens considered so far: 22342
Processed batch. Total tokens considered so far: 22622
Processed batch. Total tokens considered so far: 22918
Processed batch. Total tokens considered so far: 23176
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Processed batch. Total tokens considered so far: 23423
Processed batch. Total tokens considered so far: 23685
Processed batch. Total tokens considered so far: 24001
Processed batch. Total tokens considered so far: 24335
Processed batch. Total tokens considered so far: 24618
Processed batch. Total tokens considered so far: 24936
Processed batch. Total tokens considered so far: 25204
Processed batch. Total tokens considered so far: 25503
Processed batch. Total tokens considered so far: 25808
Processed batch. Total tokens considered so far: 26103
Processed batch. Total tokens considered so far: 26356
Processed batch. Total tokens considered so far: 26611
Processed batch. Total tokens considered so far: 26855
Processed batch. Total tokens considered so far: 27103
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Processed batch. Total tokens considered so far: 27635
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Processed batch. Total tokens considered so far: 28175
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Processed batch. Total tokens considered so far: 28701
Processed batch. Total tokens considered so far: 28978
Processed batch. Total tokens considered so far: 29230
Processed batch. Total tokens considered so far: 29475
Processed batch. Total tokens considered so far: 29747
Processed batch. Total tokens considered so far: 30021
Processed batch. Total tokens considered so far: 30276
Processed batch. Total tokens considered so far: 30594
Processed batch. Total tokens considered so far: 30872
Processed batch. Total tokens considered so far: 31159
Processed batch. Total tokens considered so far: 31440
Processed batch. Total tokens considered so far: 31731
Processed batch. Total tokens considered so far: 32015
Processed batch. Total tokens considered so far: 32292
Processed batch. Total tokens considered so far: 32575
Processed batch. Total tokens considered so far: 32850
Processed batch. Total tokens considered so far: 33137
Processed batch. Total tokens considered so far: 33397
Processed batch. Total tokens considered so far: 33726
Processed batch. Total tokens considered so far: 34031
Processed batch. Total tokens considered so far: 34296
Processed batch. Total tokens considered so far: 34557
Processed batch. Total tokens considered so far: 34832
Processed batch. Total tokens considered so far: 35160
Processed batch. Total tokens considered so far: 35468
Processed batch. Total tokens considered so far: 35796
Processed batch. Total tokens considered so far: 36128
Processed batch. Total tokens considered so far: 36448
Processed batch. Total tokens considered so far: 36764
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Processed batch. Total tokens considered so far: 37088
Processed batch. Total tokens considered so far: 37413
Processed batch. Total tokens considered so far: 37706
Processed batch. Total tokens considered so far: 38020
Processed batch. Total tokens considered so far: 38328
Processed batch. Total tokens considered so far: 38648
Processed batch. Total tokens considered so far: 38943
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Processed batch. Total tokens considered so far: 39588
Processed batch. Total tokens considered so far: 39894
Processed batch. Total tokens considered so far: 40186
Processed batch. Total tokens considered so far: 40476
Processed batch. Total tokens considered so far: 40763
Processed batch. Total tokens considered so far: 41064
Processed batch. Total tokens considered so far: 41326
Processed batch. Total tokens considered so far: 41633
Processed batch. Total tokens considered so far: 41926
Processed batch. Total tokens considered so far: 42221
Processed batch. Total tokens considered so far: 42559
Processed batch. Total tokens considered so far: 42896
Processed batch. Total tokens considered so far: 43238
Processed batch. Total tokens considered so far: 43567
Processed batch. Total tokens considered so far: 43877
Processed batch. Total tokens considered so far: 44172
Processed batch. Total tokens considered so far: 44431
Processed batch. Total tokens considered so far: 44716
Processed batch. Total tokens considered so far: 44998
Processed batch. Total tokens considered so far: 45303
Processed batch. Total tokens considered so far: 45625
Processed batch. Total tokens considered so far: 45917
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Processed batch. Total tokens considered so far: 46466
Processed batch. Total tokens considered so far: 46720
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Processed batch. Total tokens considered so far: 47353
Processed batch. Total tokens considered so far: 47672
Processed batch. Total tokens considered so far: 47946
Processed batch. Total tokens considered so far: 48234
Processed batch. Total tokens considered so far: 48509
Processed batch. Total tokens considered so far: 48772
Processed batch. Total tokens considered so far: 49066
Processed batch. Total tokens considered so far: 49347
Processed batch. Total tokens considered so far: 49618
Processed batch. Total tokens considered so far: 49884
Processed batch. Total tokens considered so far: 50148
Processed batch. Total tokens considered so far: 50429
Processed batch. Total tokens considered so far: 50683
Processed batch. Total tokens considered so far: 50982
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Processed batch. Total tokens considered so far: 51245
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Processed batch. Total tokens considered so far: 51856
Processed batch. Total tokens considered so far: 52140
Processed batch. Total tokens considered so far: 52424
Processed batch. Total tokens considered so far: 52718
Processed batch. Total tokens considered so far: 53011
Processed batch. Total tokens considered so far: 53301
Processed batch. Total tokens considered so far: 53573
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Processed batch. Total tokens considered so far: 55267
Processed batch. Total tokens considered so far: 55553
Processed batch. Total tokens considered so far: 55842
Processed batch. Total tokens considered so far: 56102
Processed batch. Total tokens considered so far: 56361
Processed batch. Total tokens considered so far: 56639
Processed batch. Total tokens considered so far: 56965
Processed batch. Total tokens considered so far: 57309
Processed batch. Total tokens considered so far: 57639
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Processed batch. Total tokens considered so far: 58550
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Processed batch. Total tokens considered so far: 62896
Processed batch. Total tokens considered so far: 63141
Processed batch. Total tokens considered so far: 63389
Processed batch. Total tokens considered so far: 63639
Processed batch. Total tokens considered so far: 63971
Processed batch. Total tokens considered so far: 64292
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Processed batch. Total tokens considered so far: 65223
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Processed batch. Total tokens considered so far: 66531
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Processed batch. Total tokens considered so far: 76456
Processed batch. Total tokens considered so far: 76712
Processed batch. Total tokens considered so far: 76963
Processed batch. Total tokens considered so far: 77237
Processed batch. Total tokens considered so far: 77511
Processed batch. Total tokens considered so far: 77761
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Processed batch. Total tokens considered so far: 78032
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Processed batch. Total tokens considered so far: 79185
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Processed batch. Total tokens considered so far: 82197
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Processed batch. Total tokens considered so far: 87644
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Processed batch. Total tokens considered so far: 88984
Processed batch. Total tokens considered so far: 89322
Processed batch. Total tokens considered so far: 89629
Processed batch. Total tokens considered so far: 89937
Processed batch. Total tokens considered so far: 90243
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Processed batch. Total tokens considered so far: 90833
Processed batch. Total tokens considered so far: 91169
Processed batch. Total tokens considered so far: 91436
Processed batch. Total tokens considered so far: 91688
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Processed batch. Total tokens considered so far: 91963
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Processed batch. Total tokens considered so far: 92491
Processed batch. Total tokens considered so far: 92763
Processed batch. Total tokens considered so far: 93040
Processed batch. Total tokens considered so far: 93330
Processed batch. Total tokens considered so far: 93651
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Processed batch. Total tokens considered so far: 95619
Processed batch. Total tokens considered so far: 95862
Processed batch. Total tokens considered so far: 96139
Processed batch. Total tokens considered so far: 96430
Processed batch. Total tokens considered so far: 96684
Processed batch. Total tokens considered so far: 97016
Processed batch. Total tokens considered so far: 97396
Processed batch. Total tokens considered so far: 97760
Processed batch. Total tokens considered so far: 98103
Processed batch. Total tokens considered so far: 98456
Processed batch. Total tokens considered so far: 98723
Processed batch. Total tokens considered so far: 98984
Processed batch. Total tokens considered so far: 99264
Processed batch. Total tokens considered so far: 99518
Processed batch. Total tokens considered so far: 99793
Processed batch. Total tokens considered so far: 100074
Processed batch. Total tokens considered so far: 100345
Processed batch. Total tokens considered so far: 100618
Processed batch. Total tokens considered so far: 100900
Processed batch. Total tokens considered so far: 101170
Processed batch. Total tokens considered so far: 101423
Processed batch. Total tokens considered so far: 101687
Processed batch. Total tokens considered so far: 101964
Processed batch. Total tokens considered so far: 102230
Processed batch. Total tokens considered so far: 102492
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Processed batch. Total tokens considered so far: 103285
Processed batch. Total tokens considered so far: 103547
Processed batch. Total tokens considered so far: 103869
Processed batch. Total tokens considered so far: 104126
Processed batch. Total tokens considered so far: 104371
Processed batch. Total tokens considered so far: 104602
Processed batch. Total tokens considered so far: 104912
Processed batch. Total tokens considered so far: 105305
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Processed batch. Total tokens considered so far: 105727
Processed batch. Total tokens considered so far: 106096
Processed batch. Total tokens considered so far: 106471
Processed batch. Total tokens considered so far: 106819
Processed batch. Total tokens considered so far: 107084
Processed batch. Total tokens considered so far: 107365
Processed batch. Total tokens considered so far: 107633
Processed batch. Total tokens considered so far: 107898
Processed batch. Total tokens considered so far: 108169
Processed batch. Total tokens considered so far: 108460
Processed batch. Total tokens considered so far: 108726
Processed batch. Total tokens considered so far: 109042
Processed batch. Total tokens considered so far: 109305
Processed batch. Total tokens considered so far: 109601
Processed batch. Total tokens considered so far: 109896
Processed batch. Total tokens considered so far: 110179
Processed batch. Total tokens considered so far: 110464
Processed batch. Total tokens considered so far: 110738
Processed batch. Total tokens considered so far: 111027
Processed batch. Total tokens considered so far: 111311
Processed batch. Total tokens considered so far: 111600
Processed batch. Total tokens considered so far: 111873
Processed batch. Total tokens considered so far: 112169
Processed batch. Total tokens considered so far: 112452
Processed batch. Total tokens considered so far: 112745
Processed batch. Total tokens considered so far: 113013
Processed batch. Total tokens considered so far: 113295
Processed batch. Total tokens considered so far: 113582
Processed batch. Total tokens considered so far: 113865
Processed batch. Total tokens considered so far: 114138
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Processed batch. Total tokens considered so far: 115061
Processed batch. Total tokens considered so far: 115358
Processed batch. Total tokens considered so far: 115653
Processed batch. Total tokens considered so far: 115934
Processed batch. Total tokens considered so far: 116215
Processed batch. Total tokens considered so far: 116497
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Processed batch. Total tokens considered so far: 342619
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Processed batch. Total tokens considered so far: 351603
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  Processed batch. Total tokens considered so far: 351936
  Processed batch. Total tokens considered so far: 352260
  Processed batch. Total tokens considered so far: 352550
  Processed batch. Total tokens considered so far: 352821
  Processed batch. Total tokens considered so far: 353102
  Processed batch. Total tokens considered so far: 353361
  Processed batch. Total tokens considered so far: 353643
  Processed batch. Total tokens considered so far: 353919
  Processed batch. Total tokens considered so far: 354216
  Processed batch. Total tokens considered so far: 354480
  Processed batch. Total tokens considered so far: 354752
  Processed batch. Total tokens considered so far: 355043
  Processed batch. Total tokens considered so far: 355343
  Processed batch. Total tokens considered so far: 355610
  Processed batch. Total tokens considered so far: 355898
  Processed batch. Total tokens considered so far: 356179
  Processed batch. Total tokens considered so far: 356465
  Processed batch. Total tokens considered so far: 356779
  Processed batch. Total tokens considered so far: 356930
--- Metrics Calculation Complete. Total tokens analyzed: 356930 ---
  Calculated Metrics - Precision: 0.9983, Recall: 0.9989, F1 Score: 0.9986
Transformer Evaluation Metrics:
  Precision: 0.9983
  Recall: 0.9989
  F1-score: 0.9986
Training and evaluation completed.
[INFO] Restored standard output/error streams.
```

2.12 Cleanup

[21]:
```python
import os

files_to_remove = [
    log_filename,
    report_filename,
    loss_plot_filename,
    conf_matrix_filename,
    model_save_filename,
    # csv_filename # Be careful removing the CSV
]

# For simplicity, we'll just check if it's the default name and small size
csv_check_path = "food_predictions.csv"
if os.path.exists(csv_check_path):
     # A simple check, might need refinement
     if os.path.getsize(csv_check_path) < 1024:
```

```
            print(f"[Cleanup] Identified '{csv_check_path}', adding to removal␣
 ↪list.")
            files_to_remove.append(csv_check_path)
        else:
             print(f"[Cleanup] Skipping removal of '{csv_check_path}' as it might␣
 ↪contain real data.")

print("\n--- Cleaning up generated files ---")
for filename in files_to_remove:
    try:
        if os.path.exists(filename):
            os.remove(filename)
            print(f"Removed: {filename}")
        else:
            print(f"Skipped (Not Found): {filename}")
    except OSError as e:
        print(f"Error removing {filename}: {e}")

print("--- Cleanup Finished --- ")
```

```
[Cleanup] Skipping removal of 'food_predictions.csv' as it might contain real
data.

--- Cleaning up generated files ---
Removed: log.txt
Removed: report.html
Removed: training_validation_loss.png
Skipped (Not Found): confusion_matrix.png
Skipped (Not Found): trained_model.pth
--- Cleanup Finished ---
```