Final project

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Introduction

The original idea on this project was using Sentence Transformers(SBERT, for reference view https://sbert.net/) embedding to classify, human and AI generated text. However this attempt was unsuccessful because features that were extracted from SBERT failed to capture any significant information as shown in t-SNE plot below. Seeing this, choose to fine tune pretrained LLM RoBERTa.

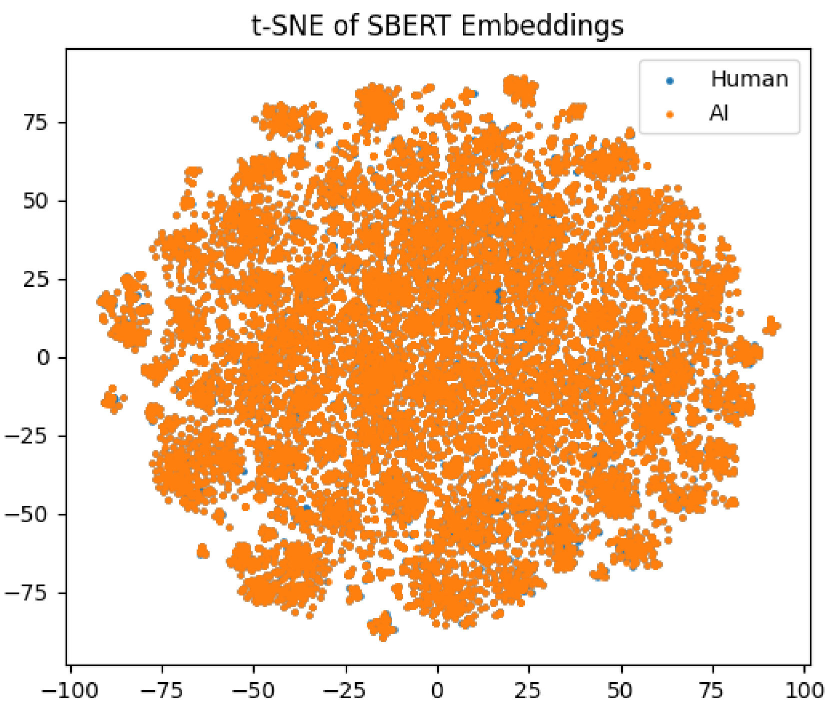


Figure 1: t-SNE plot of SBERT feature

Theoretical Background

In this study, several foundational concepts in natural language processing and deep learning are used to distinguish between AI- and human-written texts. **RoBERTa**, an improved version of BERT, is employed for its optimized pretraining strategies and enhanced language understanding. The model architecture is based on the **Transformer**, which relies solely on **attention mechanisms** to process sequential data efficiently.

The attention mechanism helps the model focus on relevant parts of the input, allowing better context understanding.

At a lower level, the **perceptron** serves as the basic unit of deep neural networks, supporting more complex architectures like multi-layer networks. **Large Language Models (LLMs)**, such as ChatGPT, generate coherent text by predicting word sequences based on prior data. These models are trained using **backpropagation**, a method that calculates gradients using the **chain rule** to adjust model parameters.

Fine-tuning is applied to adapt a pre-trained model to a specific dataset, improving task-specific performance. In this project, RoBERTa is fine-tuned to classify U.S. Senate press releases as either human- or AI-generated, utilizing these core principles in a practical application.

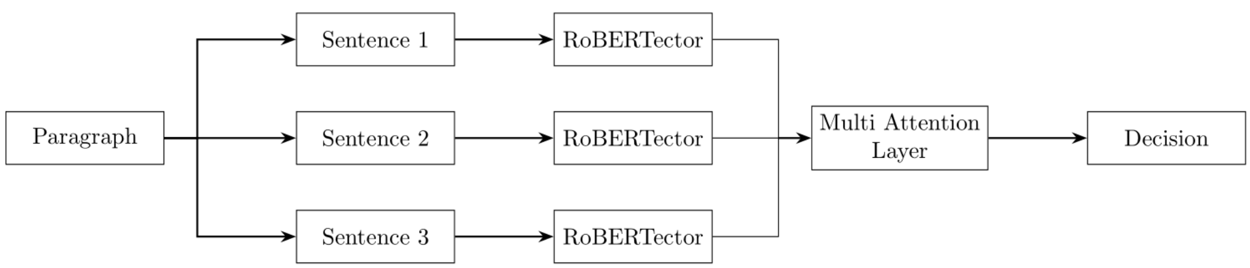
Methods

Our approach combines sentence-level encoding with a multi-attention mechanism to classify paragraph-level text.

RoBERTector

RoBERTector is finetuned RoBerta that specify on AI detection on sentence level. it's predeictive abilitwes were Accuracy: 0.8648 F1 Score: 0.8644 on validation set.

Architecture



Model Architecture in Prose

Our model begins by **splitting each paragraph** into at most 16 sentences. We scan for sentence delimiters (`.`, `?`, `!`), trim whitespace, and discard empty fragments. If a paragraph produces fewer than 16 sentences, we pad the remainder with dummy tokens; if it exceeds 16, we simply truncate after the 16th. This approach guarantees every input tensor has a fixed shape `(batch_size × 16 × max_length)`, which simplifies batching and avoids dynamic control-flow overhead.

Next, each of these up to 16 sentence slots is **encoded independently** by RoBERTector(a RoBERTa model that was previously fine-tuned on sentence-level AI vs. human text classification). By freezing all of RoBERTector's parameters, we preserve its robust ability to capture subtle stylistic and lexical cues (word choice, phrasing patterns, function-word frequencies) without risking over-fitting on our comparatively small paragraph dataset. From each sentence's transformer output we extract the `CLS` token embedding (a 768-dimensional vector), producing a tensor of shape `(batch_size, 16, 768)`.

These 16 sentence embeddings are then fed into a **multi-head self-attention layer** (four heads, embed_dim=768). Because the Query, Key, and Value all derive from the same set of sentence embeddings, the attention mechanism learns to assign higher weights to the most informative sentences—thesis statements, topic transitions, or discourse markers—while down-weighting less relevant ones. The attended outputs are mean-pooled across the sentence axis, yielding a single 768-dimensional "paragraph embedding" that fuses both micro-level sentence cues and macro-level discourse structure.

Finally, a **lightweight classification head** (a two-layer MLP with ReLU and dropout) maps this paragraph embedding to a single logit. We apply `BCEWithLogitsLoss` during training—combining sigmoid activation and binary cross-entropy in a numerically stable way—and use a 0.5 threshold on the sigmoid probability to make the AI vs. human decision. We train only the attention and MLP head (leaving RoBERTector frozen), save model checkpoints after every epoch, and evaluate on an 80/10/10 train/val/test split of our ~20 000-paragraph dataset (with test performed just once at the end).

By **reusing** a specialized sentence encoder, **learning** which sentences truly matter via attention, and **regularizing** most of the model by freezing, this architecture achieves high accuracy and generalization while remaining interpretable: attention weights can be visualized to show exactly which sentences drove each classification.

Set up python enviroment

Install packages

Load data and split paragraphs into sentences

```python
import pandas as pd
df=pd.read_csv('/kaggle/input/ai-text/ai_press_releases.csv')
df=df.dropna()
human=df['non_chat_gpt_press_release']
ai=df['chat_gpt_generated_release']
hu=[]
a=[]
for i in human:
    l=list(i.split('. '))
    hu.extend(l)
for i in ai:
    l=list(i.split('. '))
    a.extend(l)

ap=a.copy()
a.extend(hu)
texts=a
labels=[0 if i<len(ap) else 1 for i in range(len(texts))]
from sklearn.model_selection import train_test_split

#split train, test and validation data.
texts_train_val, texts_test, labels_train_val, labels_test = train_test_split(
    texts,
    labels,
    test_size=0.2,       # 20% of the entire dataset
    random_state=42,
    stratify=labels      # Maintain label distribution
)

# 2) Split train_temp again into train (75% of temp → 60% of the total) and val (25% of temp → 20% of t
texts_train, texts_val, labels_train, labels_val = train_test_split(
    texts_train_val,
    labels_train_val,
    test_size=0.25,      #25% of train_temp → 0.2 of total
    random_state=42,
```

```
    stratify=labels_train_val
)

print(f"Train: {len(texts_train)} samples")
print(f"Valid: {len(texts_val)} samples")
print(f"Test : {len(texts_test)} samples")
```

Load Roberta and fine tune

```
import torch
from torch.utils.data import DataLoader
from transformers import AutoTokenizer, AutoModelForSequenceClassification
from torch.optim import AdamW
from datasets import Dataset
from tqdm.auto import tqdm
from sklearn.metrics import accuracy_score, f1_score

# Load pretrained tokenizer
tokenizer = AutoTokenizer.from_pretrained("roberta-base")

# Function to prepare batch inputs
def collate_fn(batch):
    enc = tokenizer(
        [x["text"] for x in batch],  # Extract texts
        padding="longest",           # Pad to the longest in batch
        truncation=True,             # Truncate if too long
        max_length=256,              # Limit to 256 tokens
        return_tensors="pt"          # Return PyTorch tensors
    )
    enc["labels"] = torch.tensor([x["label"] for x in batch], dtype=torch.long)
    return enc

# Convert to HuggingFace Dataset format
train_ds = Dataset.from_dict({"text": texts_train, "label": labels_train})
val_ds   = Dataset.from_dict({"text": texts_val,   "label": labels_val})
test_ds  = Dataset.from_dict({"text": texts_test,  "label": labels_test})

# Create PyTorch DataLoaders
train_loader = DataLoader(train_ds, batch_size=16, shuffle=True, collate_fn=collate_fn)
val_loader   = DataLoader(val_ds,   batch_size=32, shuffle=False, collate_fn=collate_fn)
test_loader  = DataLoader(test_ds,  batch_size=32, shuffle=False, collate_fn=collate_fn)

# Model and optimizer configuration
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")  # Use GPU if available
model  = AutoModelForSequenceClassification.from_pretrained("roberta-base", num_labels=2).to(device)  #
optim  = AdamW(model.parameters(), lr=2e-5)  # Use AdamW optimizer

num_epochs = 8  # Train for 8 epochs

# Training loop
for epoch in range(1, num_epochs+1):
```

```python
    # 1) Training phase
    model.train()
    train_loop = tqdm(train_loader, desc=f"Epoch {epoch}/{num_epochs} [TRAIN]")  # Show progress
    for batch in train_loop:
        batch = {k: v.to(device) for k, v in batch.items()}  # Move to GPU
        outputs = model(**batch)  # Forward pass
        loss    = outputs.loss
        optim.zero_grad()  # Reset gradients
        loss.backward()  # Backpropagation
        optim.step()  # Update weights
        gpu_mem = torch.cuda.memory_allocated(device) // (1024**2)  # Monitor GPU memory
        train_loop.set_postfix(loss=f"{loss.item():.4f}", gpu_mem=f"{gpu_mem}MiB")

    # 2) Validation phase
    model.eval()
    all_preds, all_labels = [], []
    val_loop = tqdm(val_loader, desc=f"Epoch {epoch}/{num_epochs} [VAL]  ")
    with torch.no_grad():  # Disable gradient tracking
        for batch in val_loop:
            batch = {k: v.to(device) for k, v in batch.items()}
            logits = model(**batch).logits
            preds  = torch.argmax(logits, dim=-1).cpu().tolist()
            labels = batch["labels"].cpu().tolist()
            all_preds += preds
            all_labels += labels
    val_acc = accuracy_score(all_labels, all_preds)  # Compute accuracy
    val_f1  = f1_score(all_labels, all_preds, average="weighted")  # Compute weighted F1
    print(f"→ Validation | Acc: {val_acc:.4f}, F1: {val_f1:.4f}")

    # 3) Test phase (for monitoring)
    all_preds, all_labels = [], []
    test_loop = tqdm(test_loader, desc=f"Epoch {epoch}/{num_epochs} [TEST] ")
    with torch.no_grad():
        for batch in test_loop:
            batch = {k: v.to(device) for k, v in batch.items()}
            logits = model(**batch).logits
            preds  = torch.argmax(logits, dim=-1).cpu().tolist()
            labels = batch["labels"].cpu().tolist()
            all_preds += preds
            all_labels += labels
    test_acc = accuracy_score(all_labels, all_preds)
    test_f1  = f1_score(all_labels, all_preds, average="weighted")
    print(f"→ Test       | Acc: {test_acc:.4f}, F1: {test_f1:.4f}")

    # 4) Save model
    save_dir = f"/kaggle/working/checkpoint-epoch{epoch}"  # Output directory
    model.save_pretrained(save_dir)       # Save model weights
    tokenizer.save_pretrained(save_dir)   # Save tokenizer files
    print(f"→ Model & Tokenizer saved to: {save_dir}\n")
```

Training Multi Attention Layer

Load packages

```
import torch
from torch.utils.data import DataLoader
from transformers import AutoTokenizer, AutoModelForSequenceClassification
from transformers import get_linear_schedule_with_warmup
from torch.optim import AdamW
from datasets import Dataset
from tqdm.auto import tqdm
from sklearn.metrics import accuracy_score, f1_score
import pandas as pd
from sklearn.model_selection import train_test_split
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader, random_split
import random
import os
def set_seed(seed=42):
    random.seed(seed)
    torch.manual_seed(seed)
    torch.cuda.manual_seed_all(seed)

set_seed(42)
```

Load data

```
df=pd.read_csv('/kaggle/input/ai-text/ai_press_releases.csv')
df=df.dropna()
human=df['non_chat_gpt_press_release'].to_list()
ai=df['chat_gpt_generated_release'].to_list()
labels=[0 if i<len(ai) else 1 for i in range(len(ai)+len(human))]
ai.extend(human)
texts=ai
# 1)   train_temp(80%)  test(20%)
texts_train_val, texts_test, labels_train_val, labels_test = train_test_split(
    texts,
    labels,
    test_size=0.2,       #   20%
    random_state=42,
    stratify=labels      #
)

# 2) train_temp    train(75% of temp → 60%  ) val(25% of temp → 20%  )
texts_train, texts_val, labels_train, labels_val = train_test_split(
    texts_train_val,
    labels_train_val,
    test_size=0.25,      # train_temp  25% →    0.2
    random_state=42,
    stratify=labels_train_val
)
```

```python
print(f"Train: {len(texts_train)} samples")
print(f"Valid: {len(texts_val)} samples")
print(f"Test : {len(texts_test)} samples")
```

Define helper and Multiattention layer class

```python
# 2. Sentence split
def split_sentences(paragraph: str):
    return [s.strip() for s in paragraph.split('. ') if s.strip()]

# 3. Dataset
class ParagraphDataset(Dataset):
    def __init__(self, texts, labels, tokenizer, max_sents=16, max_len=128):
        self.texts = texts
        self.labels = labels
        self.tokenizer = tokenizer
        self.max_sents = max_sents
        self.max_len = max_len

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

    def __getitem__(self, i):
        para = self.texts[i]
        label = torch.tensor(self.labels[i], dtype=torch.float)
        sents = split_sentences(para)[:self.max_sents]
        encs = [self.tokenizer(s, truncation=True, padding='max_length',
                               max_length=self.max_len, return_tensors='pt')
                for s in sents]
        # pad sentences
        pad_n = self.max_sents - len(encs)
        input_ids = torch.stack([e['input_ids'].squeeze(0) for e in encs] +
                                [torch.zeros(self.max_len, dtype=torch.long)]*pad_n)
        attn_mask = torch.stack([e['attention_mask'].squeeze(0) for e in encs] +
                                [torch.zeros(self.max_len, dtype=torch.long)]*pad_n)
        return input_ids, attn_mask, label

# 4. Model: frozen encoder + attention + classifier
import torch
import torch.nn as nn
from transformers import AutoTokenizer, AutoModelForSequenceClassification

class HierAttnClassifier(nn.Module):
    def __init__(self,
                 base_model_name="/kaggle/input/robertector/transformers/sentences/1/checkpoint-epoch3"
                 max_sents=16,
                 hidden=768,
                 heads=4):
        super().__init__()
        # 1) Load your fine-tuned SequenceClassification model
        self.full_model = AutoModelForSequenceClassification.from_pretrained(
```

```python
            base_model_name, output_hidden_states=True, return_dict=True
        )
        # 2) Freeze all its parameters
        for p in self.full_model.parameters():
            p.requires_grad = False

        # 3) Multi-Head Attention on the CLS embeddings
        self.attn = nn.MultiheadAttention(embed_dim=hidden,
                                          num_heads=heads,
                                          batch_first=True)
        # 4) Final MLP head after attention
        self.classifier = nn.Sequential(
            nn.Linear(hidden, hidden // 2),
            nn.ReLU(),
            nn.Dropout(0.1),
            nn.Linear(hidden // 2, 1),
        )

    def forward(self, input_ids, attention_mask):
        b, s, l = input_ids.size()
        # flatten to (b*s, l)
        flat_ids   = input_ids.view(b * s, l)
        flat_mask  = attention_mask.view(b * s, l)
        # 5) Run through RoBERTector; we asked for hidden_states
        outputs = self.full_model(
            input_ids=flat_ids,
            attention_mask=flat_mask,
        )
        # 6) Grab the last hidden layer states: outputs.hidden_states is a tuple
        #    where hidden_states[-1] is (batch, seq_len, hidden)
        last_hid = outputs.hidden_states[-1]
        # CLS is token 0
        cls_embs = last_hid[:, 0, :].view(b, s, -1)  # (b, s, hidden)

        # 7) Self-attention over the s sentence embeddings
        attn_out, _ = self.attn(cls_embs, cls_embs, cls_embs)  # (b, s, hidden)

        # 8) Pool and classify
        doc_emb = attn_out.mean(dim=1)                        # (b, hidden)
        logits = self.classifier(doc_emb).squeeze(-1)        # (b,)
        return logits
```

Load RoBERTector and set up hyperparameters

```python
# 5. Prepare data, loaders, model, optimizer
model_path = "/kaggle/input/robertector/transformers/sentences/1/checkpoint-epoch3"
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

# Load the tokenizer from the directory
# This reads files like tokenizer.json and tokenizer_config.json
tokenizer = AutoTokenizer.from_pretrained(model_path)
```

```python
# Load the model from the directory
model = AutoModelForSequenceClassification.from_pretrained(model_path).to(device)
dataset = ParagraphDataset(texts, labels, tokenizer)
n = len(dataset)

train_n = int(0.6*n); val_n = int(0.2*n); test_n = n - train_n - val_n
train_ds, val_ds, test_ds = random_split(dataset, [train_n, val_n, test_n])
train_loader = DataLoader(train_ds, batch_size=64, shuffle=True, num_workers=2)
val_loader   = DataLoader(val_ds, batch_size=64, num_workers=2)
test_loader  = DataLoader(test_ds, batch_size=64, num_workers=2)

device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
model = HierAttnClassifier().to(device)
opt = torch.optim.AdamW(filter(lambda p: p.requires_grad, model.parameters()), lr=1e-4)
criterion = nn.BCEWithLogitsLoss()
```

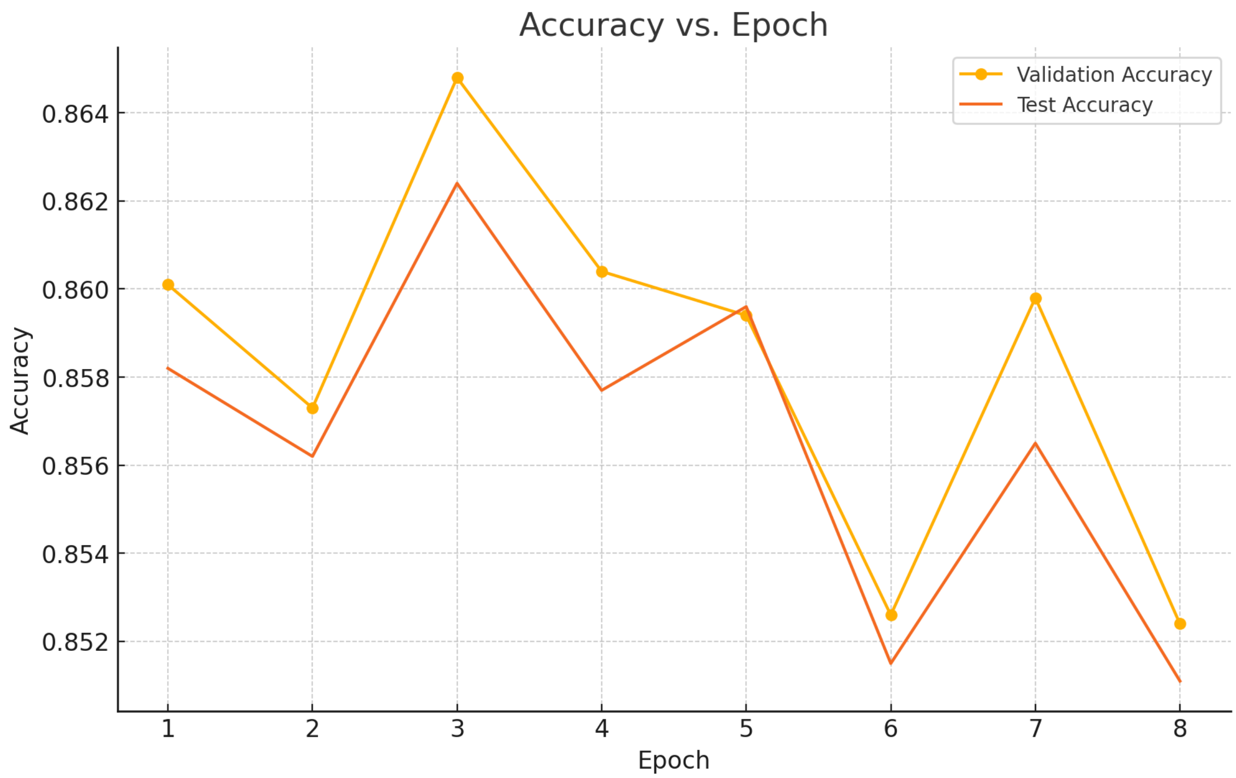
Train Multi Attention Layer

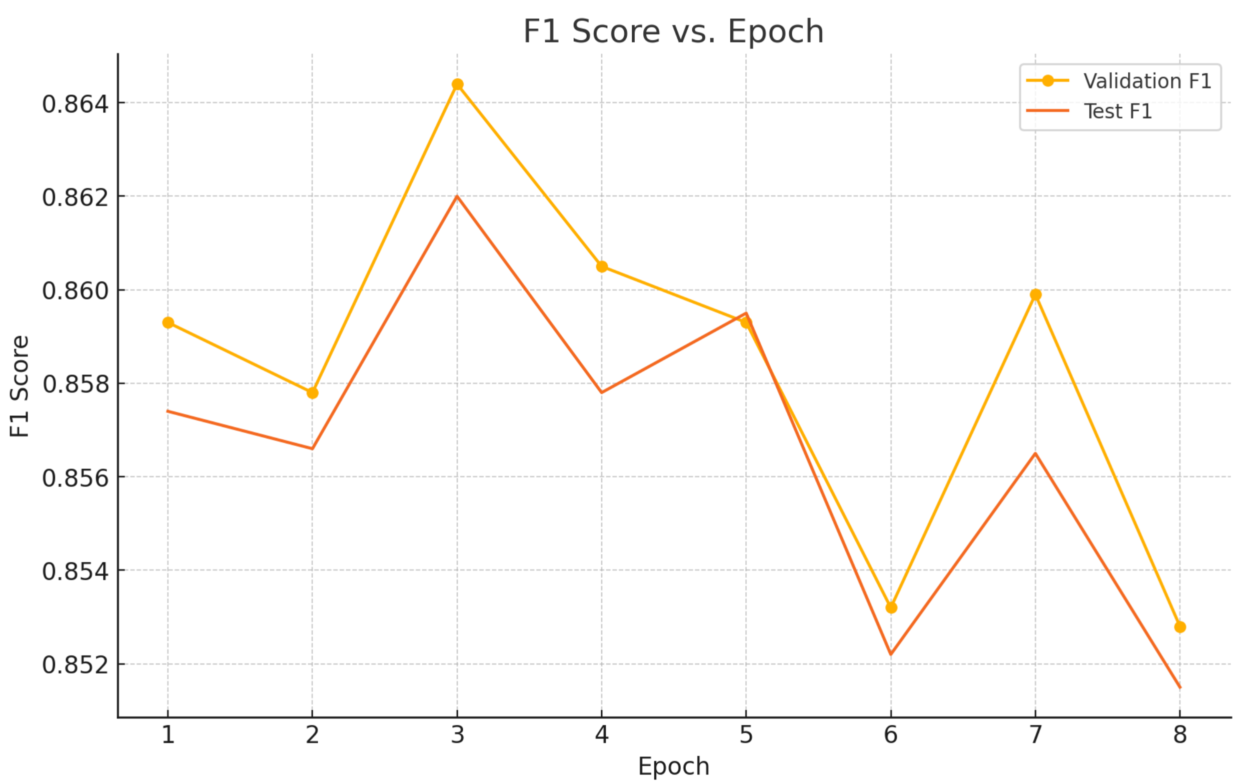
```python
from tqdm.auto import tqdm

num_epochs = 6
os.makedirs('/kaggle/working/ckpts', exist_ok=True)

for epoch in range(1, num_epochs + 1):
    #   TRAIN
    model.train()
    train_loss_sum = 0.0
    train_steps    = 0
    loop = tqdm(train_loader, desc=f"Train E{epoch}")
    for ids, mask, lbl in loop:
        ids, mask, lbl = ids.to(device), mask.to(device), lbl.to(device)
        opt.zero_grad()
        logits = model(ids, mask)
        loss   = criterion(logits, lbl)
        loss.backward()
        opt.step()

        train_loss_sum += loss.item()
        train_steps    += 1
        # tqdm
        loop.set_postfix(loss=f"{loss.item():.4f}")

    avg_train_loss = train_loss_sum / train_steps
    print(f"Epoch {epoch} | Train Loss: {avg_train_loss:.4f}")

    #   VALIDATION
    model.eval()
    val_loss_sum = 0.0
    preds, trues = [], []
    with torch.no_grad():
        for ids, mask, lbl in val_loader:
            ids, mask, lbl = ids.to(device), mask.to(device), lbl.to(device)
```

```
            logits = model(ids, mask)
            loss   = criterion(logits, lbl)
            val_loss_sum += loss.item()
            preds += (torch.sigmoid(logits) > 0.5).cpu().int().tolist()
            trues += lbl.cpu().int().tolist()
    avg_val_loss = val_loss_sum / len(val_loader)
    acc = accuracy_score(trues, preds)
    f1  = f1_score(trues, preds)
    print(f"Epoch {epoch} | Val Loss: {avg_val_loss:.4f} | Acc: {acc:.4f} | F1: {f1:.4f}")

    #   CHECKPOINT SAVE
    checkpoint_path = f"/kaggle/working/ckpts/epoch{epoch}.pt"
    torch.save(model.state_dict(), checkpoint_path)
    print(f"Saved checkpoint: {checkpoint_path}")

#   FINAL TEST
model.load_state_dict(torch.load('/kaggle/working/ckpts/epoch6.pt'))
model.eval()
preds, trues = [], []
with torch.no_grad():
    for ids, mask, lbl in test_loader:
        ids, mask, lbl = ids.to(device), mask.to(device), lbl.to(device)
        logits = model(ids, mask)
        preds += (torch.sigmoid(logits) > 0.5).cpu().int().tolist()
        trues += lbl.cpu().int().tolist()
acc = accuracy_score(trues, preds)
f1  = f1_score(trues, preds)
print(f"Test Acc {acc:.4f} | F1 {f1:.4f}")
```

Results

FineTuning





model from epoch 3 was chosen.

Training Multi Attention layer

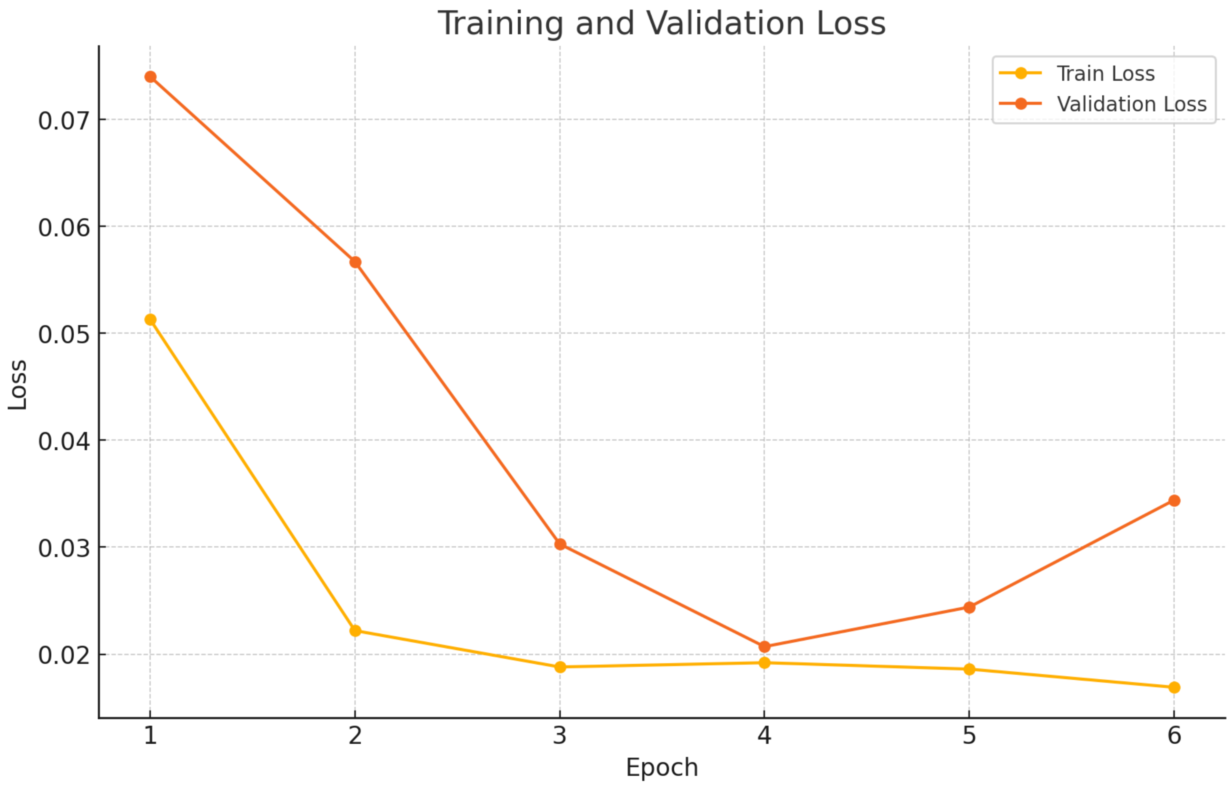
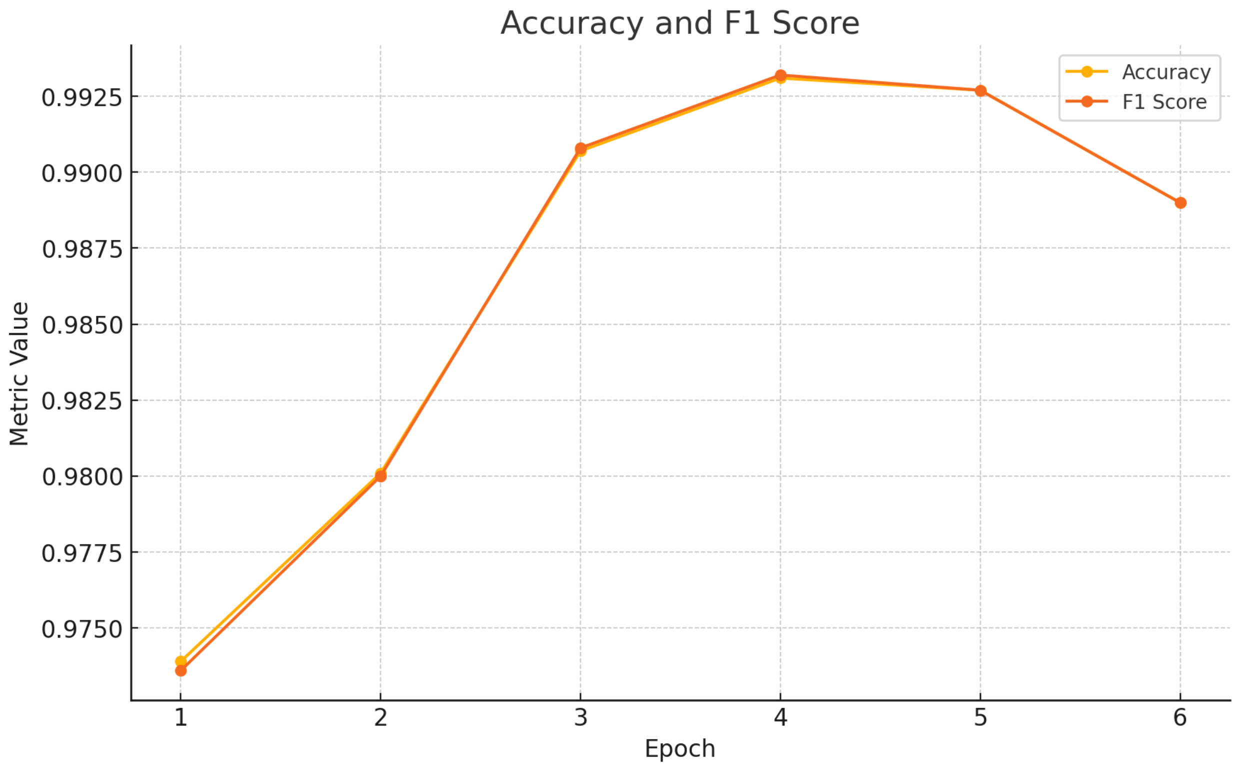


Figure 2: learning plot



model from epoch 4 was chosen.