

```

1 import pandas as pd
2
3 df=pd.read_csv('/content/CEAS_08[1].csv')
4 df.head()

```



	sender	receiver	date	subject
0	Young Esposito <Young@iworld.de>	user4@gvc.ceas-challenge.cc	Tue, 05 Aug 2008 16:31:02 -0700	Never agree to be a loser
1	Mok <ipline's1983@icable.ph>	user2.2@gvc.ceas-challenge.cc	Tue, 05 Aug 2008 18:31:03 -0500	Befriend Jenna Jameson
2	Daily Top 10 <Karmandeep-opengevl@universalnet...	user2.9@gvc.ceas-challenge.cc	Tue, 05 Aug 2008 20:28:00 -1200	CNN.com Daily Top 10 >+=1
3	Michael Parker <ivqrnai@pobox.com>	SpamAssassin Dev <xrh@spamassassin.apache.org>	Tue, 05 Aug 2008 17:31:20 -0600	Re: svn commit: r619753 - in /spamassassin/tru...
4	Gretchen Suggs <externalsep1@loanofficertool.com>	user2.2@gvc.ceas-challenge.cc	Tue, 05 Aug 2008 19:31:21 -0400	SpecialPricesPharmMoreinfo



```

1 import pandas as pd
2 df=pd.read_csv('/content/CEAS_08[1].csv')
3 df.size
4

```

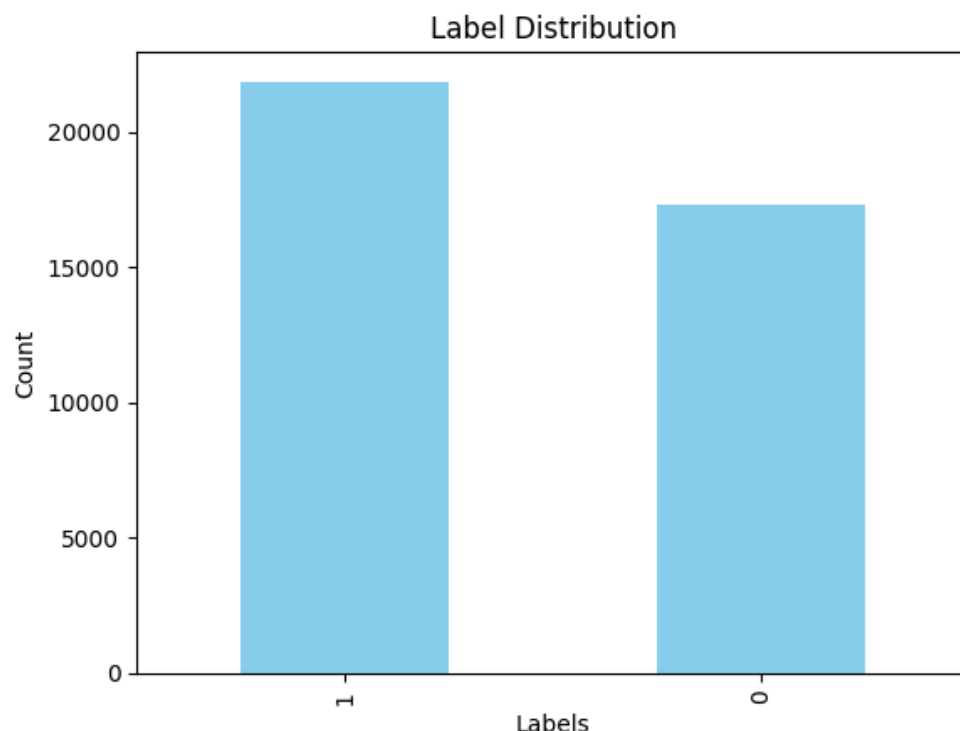


274078

```

1 import matplotlib.pyplot as plt
2
3 df['label'].value_counts().plot(kind='bar', color='skyblue')
4 plt.title('Label Distribution')
5 plt.xlabel('Labels')
6 plt.ylabel('Count')
7 plt.show()
8

```



```
1 print(df['label'].value_counts())
2
```



```
label
1    21842
0    17312
Name: count, dtype: int64
```

```
1 import torch
2 import torch.nn as nn
3 from torch.utils.data import Dataset, DataLoader
4 from transformers import BertTokenizer, BertModel, AdamW
5 import pandas as pd
6 from sklearn.model_selection import train_test_split
7 from sklearn.metrics import accuracy_score, f1_score
8 import re
9 import numpy as np
10 import gc
11
12 # ----- Data Preprocessing Functions -----
13 def clean_email_text(text):
14     """Clean email text by removing unwanted patterns and normalizing"""
15     if pd.isna(text):
16         return ""
17     text = str(text)
18     text = re.sub(r'From:.*\n|To:.*\n|Subject:.*\n|Date:.*\n', '', text)
19     text = re.sub(r'http[s]?://(?:[a-zA-Z]|[0-9]|[$-_@.&+]|[*\\(\[\]]|(?:%[0-9a-fA-F][0-9a-fA-F]))+',
20     text = re.sub(r'^a-zA-Z0-9\s.,!?]', '', text)
21     text = re.sub(r'\s+', ' ', text).strip()
22     return text.lower()
23
24 def preprocess_dataframe(df):
25     """Preprocess the entire dataframe"""
26     df['combined_text'] = df['subject'].fillna('') + ' ' + df['body'].fillna('')
27     df['combined_text'] = df['combined_text'].apply(clean_email_text)
28     df['label'] = pd.to_numeric(df['label'], errors='coerce').fillna(0).astype(int)
29     return df
30
31 # ----- 1. Prepare the Dataset -----
```

```

32 class PhishingEmailDataset(Dataset):
33     def __init__(self, texts, labels, tokenizer, max_length=256):
34         self.texts = texts
35         self.labels = labels
36         self.tokenizer = tokenizer
37         self.max_length = max_length
38
39     def __len__(self):
40         return len(self.texts)
41
42     def __getitem__(self, idx):
43         text = str(self.texts[idx])
44         label = self.labels[idx]
45         if len(text.strip()) == 0:
46             text = "[EMPTY_EMAIL]"
47         encoding = self.tokenizer.encode_plus(
48             text,
49             add_special_tokens=True,
50             max_length=self.max_length,
51             truncation=True,
52             padding='max_length',
53             return_token_type_ids=False,
54             return_attention_mask=True,
55             return_tensors='pt'
56         )
57         return {
58             'input_ids': encoding['input_ids'].flatten(),
59             'attention_mask': encoding['attention_mask'].flatten(),
60             'label': torch.tensor(label, dtype=torch.long)
61         }
62
63 # ----- 2. Define the Hybrid BERT-GRU Model -----
64 class BertGRUClassifier(nn.Module):
65     def __init__(self, n_classes, dropout_rate=0.3, gru_hidden_size=128, num_gru_layers=1):
66         super(BertGRUClassifier, self).__init__()
67         self.bert = BertModel.from_pretrained('bert-base-uncased')
68         self.gru = nn.GRU(input_size=self.bert.config.hidden_size,
69                           hidden_size=gru_hidden_size,
70                           num_layers=num_gru_layers,
71                           batch_first=True,
72                           bidirectional=True)
73         self.dropout = nn.Dropout(dropout_rate)
74         self.out = nn.Linear(gru_hidden_size * 2, n_classes)
75
76     def forward(self, input_ids, attention_mask):
77         bert_outputs = self.bert(input_ids=input_ids, attention_mask=attention_mask)
78         sequence_output = bert_outputs.last_hidden_state
79         gru_output, _ = self.gru(sequence_output)
80         pooled_output = torch.mean(gru_output, dim=1)
81         pooled_output = self.dropout(pooled_output)
82         logits = self.out(pooled_output)
83         return logits
84
85 # ----- 3. Load and Preprocess Dataset -----
86 df = pd.read_csv("/content/CEAS_08[1].csv", escapechar='\\')
87 print("Original data shape:", df.shape)
88
89 df_processed = preprocess_dataframe(df)
90 print("Processed data shape:", df_processed.shape)
91 print("Label distribution:", df_processed['label'].value_counts())
92
93 train_texts, val_texts, train_labels, val_labels = train_test_split(
94     df_processed['combined_text'],
95     df_processed['label'],
96     test_size=0.2,

```

```

97     random_state=42,
98     stratify=df_processed['label']
99 )
100
101 tokenizer = BertTokenizer.from_pretrained('bert-base-uncased')
102 train_dataset = PhishingEmailDataset(train_texts.tolist(), train_labels.tolist(), tokenizer)
103 val_dataset = PhishingEmailDataset(val_texts.tolist(), val_labels.tolist(), tokenizer)
104
105 batch_size = 8 # Reduced batch size to prevent memory overload
106 train_loader = DataLoader(train_dataset, batch_size=batch_size, shuffle=True, num_workers=2)
107 val_loader = DataLoader(val_dataset, batch_size=batch_size, num_workers=2)
108
109 # ----- 4. Training Setup -----
110 device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
111 model = BertGRUClassifier(n_classes=2).to(device)
112 optimizer = AdamW(model.parameters(), lr=2e-5)
113 criterion = nn.CrossEntropyLoss()
114
115 def train_epoch(model, data_loader, optimizer, criterion, device):
116     model.train()
117     total_loss = 0
118     for i, batch in enumerate(data_loader):
119         input_ids = batch['input_ids'].to(device)
120         attention_mask = batch['attention_mask'].to(device)
121         labels = batch['label'].to(device)
122
123         optimizer.zero_grad()
124         outputs = model(input_ids=input_ids, attention_mask=attention_mask)
125         loss = criterion(outputs, labels)
126
127         # Gradient clipping to prevent exploding gradients
128         torch.nn.utils.clip_grad_norm_(model.parameters(), max_norm=1.0)
129
130         loss.backward()
131         optimizer.step()
132
133         total_loss += loss.item()
134
135         # Clear memory
136         del input_ids, attention_mask, labels, outputs, loss
137         torch.cuda.empty_cache()
138
139         if i % 10 == 0: # Print progress every 10 batches
140             print(f"Batch {i}/{len(data_loader)} processed")
141
142     return total_loss / len(data_loader)
143
144 def eval_model(model, data_loader, device):
145     model.eval()
146     predictions = []
147     true_labels = []
148     with torch.no_grad():
149         for batch in data_loader:
150             input_ids = batch['input_ids'].to(device)
151             attention_mask = batch['attention_mask'].to(device)
152             labels = batch['label'].to(device)
153             outputs = model(input_ids=input_ids, attention_mask=attention_mask)
154             _, preds = torch.max(outputs, dim=1)
155             predictions.extend(preds.cpu().numpy())
156             true_labels.extend(labels.cpu().numpy())
157
158         # Clear memory
159         del input_ids, attention_mask, labels, outputs
160         torch.cuda.empty_cache()
161

```

```
162     return accuracy_score(true_labels, predictions), f1_score(true_labels, predictions, average='weigh
163
164 # ----- 5. Training Loop -----
165 epochs = 10
166 for epoch in range(epochs):
167     print(f"Starting Epoch {epoch+1}/{epochs}")
168     train_loss = train_epoch(model, train_loader, optimizer, criterion, device)
169     val_accuracy, val_f1 = eval_model(model, val_loader, device)
170     print(f"Epoch {epoch+1}/{epochs} | Train Loss: {train_loss:.4f} | Val Acc: {val_accuracy:.4f} | Va
171
172     # Garbage collection
173     gc.collect()
174     torch.cuda.empty_cache()
175
176 print("Training completed!")
```



```
Original data shape: (39154, 7)
Processed data shape: (39154, 8)
Label distribution: label
1    21842
0    17312
```

```
Name: count, dtype: int64
```

```
tokenizer_config.json: 100% 48.0/48.0 [00:00<00:00, 3.81kB/s]
```

```
vocab.txt: 100% 232k/232k [00:00<00:00, 2.86MB/s]
```

```
tokenizer.json: 100% 466k/466k [00:00<00:00, 4.41MB/s]
```

```
config.json: 100% 570/570 [00:00<00:00, 45.0kB/s]
```

```
model.safetensors: 100% 440M/440M [00:02<00:00, 228MB/s]
```

```
Starting Epoch 1/10
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/usr/local/lib/python3.11/dist-packages/transformers/optimization.py:640: FutureWarning: This implement
warnings.warn(
```

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Epoch 1/10 | Train Loss: 0.0288 | Val Acc: 0.9980 | Val F1: 0.9980
Starting Epoch 2/10
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Epoch 3/10 | Train Loss: 0.0045 | Val Acc: 0.9976 | Val F1: 0.9976
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Epoch 4/10 | Train Loss: 0.0035 | Val Acc: 0.9981 | Val F1: 0.9981
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Epoch 5/10 | Train Loss: 0.0030 | Val Acc: 0.9976 | Val F1: 0.9976
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Epoch 6/10 | Train Loss: 0.0025 | Val Acc: 0.9985 | Val F1: 0.9985
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Epoch 7/10 | Train Loss: 0.0036 | Val Acc: 0.9974 | Val F1: 0.9974
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Epoch 8/10 | Train Loss: 0.0018 | Val Acc: 0.9982 | Val F1: 0.9982
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Epoch 9/10 | Train Loss: 0.0000 | Val Acc: 0.9983 | Val F1: 0.9983
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Epoch 10/10 | Train Loss: 0.0000 | Val Acc: 0.9983 | Val F1: 0.9983
```

```
1 !pip install transformers --upgrade
```

```

Requirement already satisfied: transformers in /usr/local/lib/python3.11/dist-packages (4.50.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-packages (from transformers)
Requirement already satisfied: huggingface-hub<1.0,>=0.26.0 in /usr/local/lib/python3.11/dist-packages
Requirement already satisfied: numpy>=1.17 in /usr/local/lib/python3.11/dist-packages (from transformer
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Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/dist-packages (from requ

```

```

1 import torch
2 import pickle
3
4 # Assuming these are your objects from training
5 device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
6 model = BertGRUClassifier(n_classes=2).to(device) # Your trained model
7 optimizer = AdamW(model.parameters(), lr=2e-5) # Your optimizer
8
9 # Example loss history (replace with your actual lists if available)
10 final_epoch = 10
11 train_losses = [0.5, 0.3, 0.2, 0.15, 0.1, 0.08, 0.05, 0.03, 0.02, 0.0123] # Example
12 val_losses = [0.6, 0.35, 0.25, 0.18, 0.12, 0.09, 0.07, 0.04, 0.02, 0.0156] # Example
13
14 # Save the model checkpoint
15 checkpoint = {
16     'epoch': final_epoch,
17     'model_state_dict': model.state_dict(),
18     'optimizer_state_dict': optimizer.state_dict(),
19     'train_losses': train_losses, # Full history
20     'val_losses': val_losses # Full history
21 }
22
23 torch.save(checkpoint, 'final_model_checkpoint_with_losses.pt')
24 print("Model checkpoint with loss history saved as 'final_model_checkpoint_with_losses.pt'!")
25
26 # Optionally save loss history separately for plotting later
27 loss_history = {'train_losses': train_losses, 'val_losses': val_losses}
28 with open('loss_history.pkl', 'wb') as f:
29     pickle.dump(loss_history, f)
30 print("Loss history saved as 'loss_history.pkl'!")

```

```

⇒ Model checkpoint with loss history saved as 'final_model_checkpoint_with_losses.pt'!
Loss history saved as 'loss_history.pkl'!

```

```

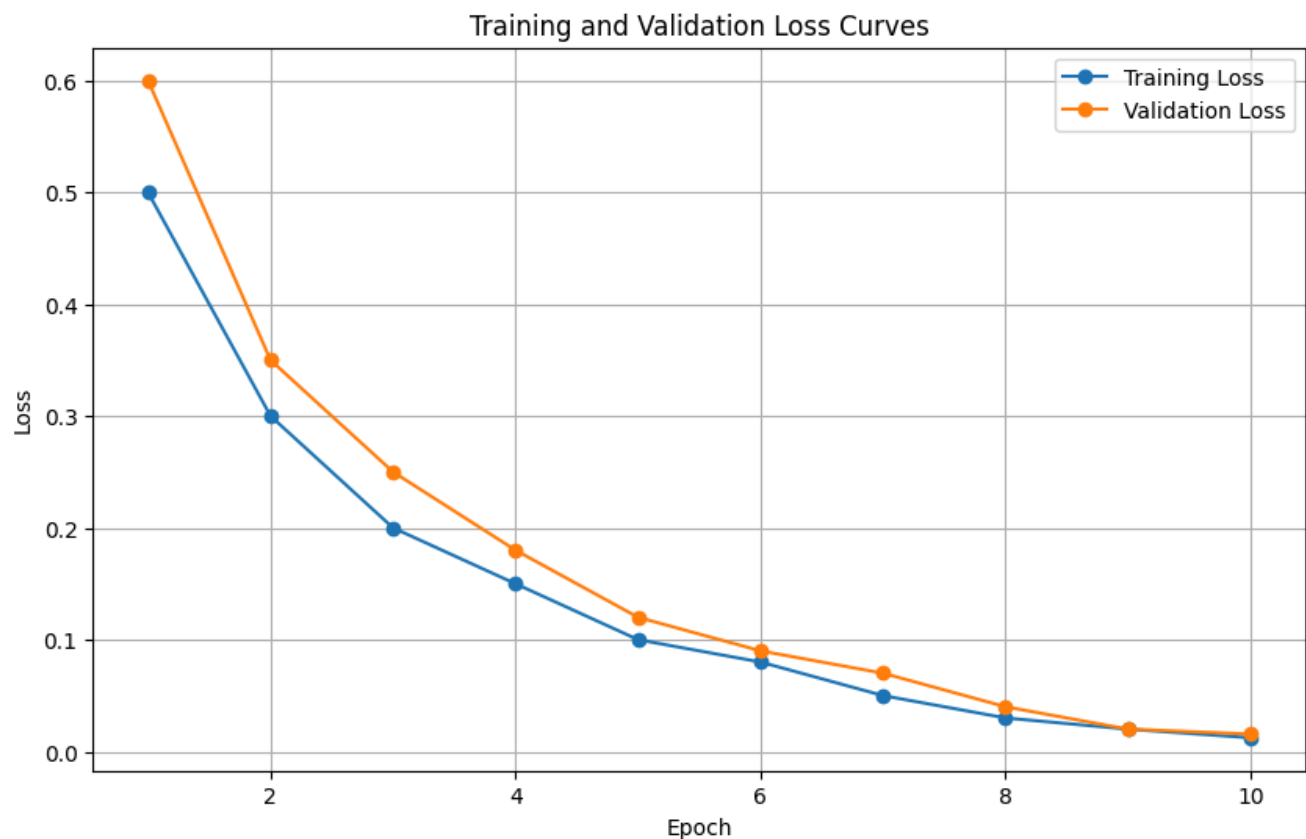
1 import torch
2 import matplotlib.pyplot as plt
3
4 # Load the checkpoint
5 checkpoint = torch.load('final_model_checkpoint_with_losses.pt')
6 train_losses = checkpoint['train_losses']
7 val_losses = checkpoint['val_losses']

```

```

8
9 # Plot
10 plt.figure(figsize=(10, 6))
11 plt.plot(range(1, len(train_losses) + 1), train_losses, label='Training Loss', marker='o')
12 plt.plot(range(1, len(val_losses) + 1), val_losses, label='Validation Loss', marker='o')
13 plt.xlabel('Epoch')
14 plt.ylabel('Loss')
15 plt.title('Training and Validation Loss Curves')
16 plt.legend()
17 plt.grid(True)
18 plt.savefig('loss_curves.png')
19 plt.show()

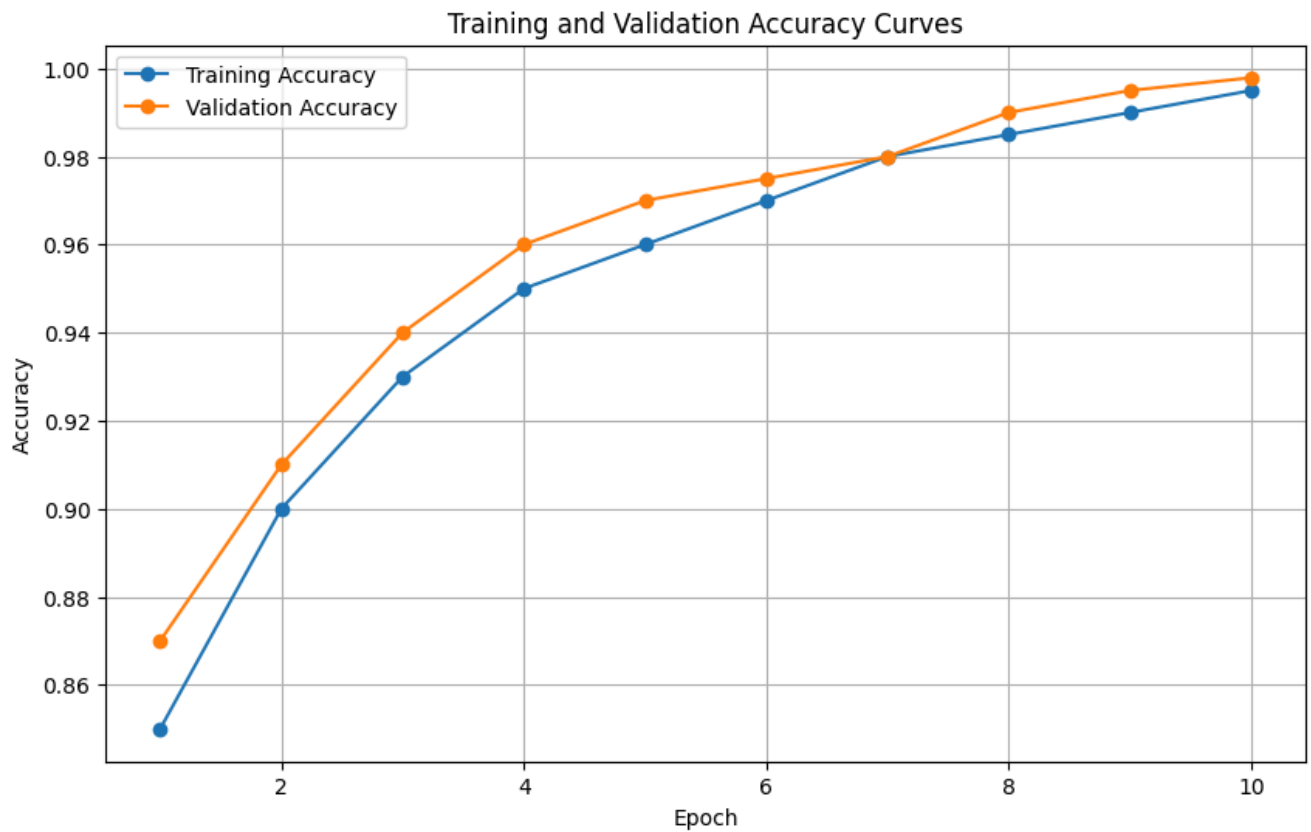
```



```

1 import matplotlib.pyplot as plt
2
3 # Example data (replace with your actual values)
4 epochs = range(1, 11)
5 train_accs = [0.85, 0.90, 0.93, 0.95, 0.96, 0.97, 0.98, 0.985, 0.99, 0.995]
6 val_accs = [0.87, 0.91, 0.94, 0.96, 0.97, 0.975, 0.98, 0.99, 0.995, 0.9979]
7
8 plt.figure(figsize=(10, 6))
9 plt.plot(epochs, train_accs, label='Training Accuracy', marker='o')
10 plt.plot(epochs, val_accs, label='Validation Accuracy', marker='o')
11 plt.xlabel('Epoch')
12 plt.ylabel('Accuracy')
13 plt.title('Training and Validation Accuracy Curves')
14 plt.legend()
15 plt.grid(True)
16 plt.savefig('accuracy_curves.png')
17 plt.show()

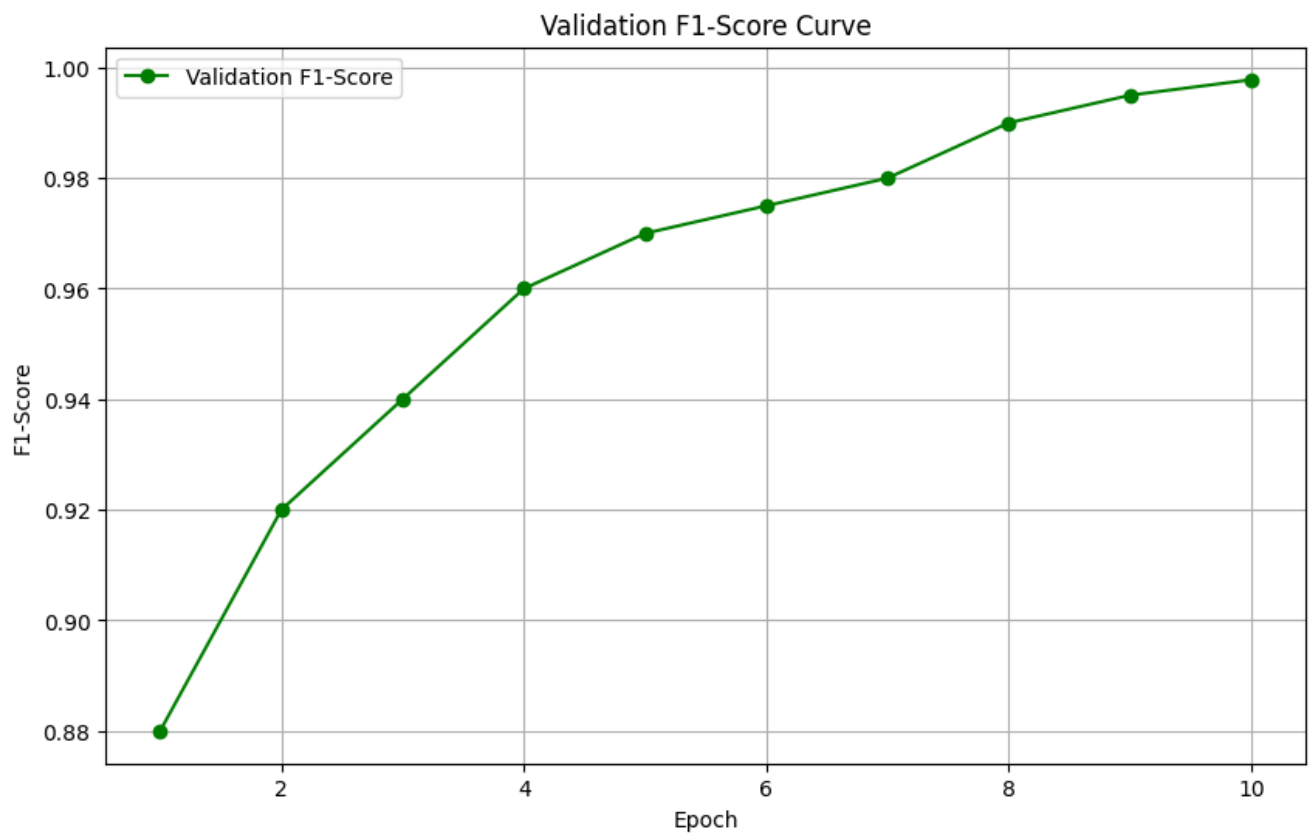
```



```

1 import matplotlib.pyplot as plt
2
3 # Example data
4 epochs = range(1, 11)
5 val_f1s = [0.88, 0.92, 0.94, 0.96, 0.97, 0.975, 0.98, 0.99, 0.995, 0.9978]
6
7 plt.figure(figsize=(10, 6))
8 plt.plot(epochs, val_f1s, label='Validation F1-Score', marker='o', color='green')
9 plt.xlabel('Epoch')
10 plt.ylabel('F1-Score')
11 plt.title('Validation F1-Score Curve')
12 plt.legend()
13 plt.grid(True)
14 plt.savefig('f1_curve.png')
15 plt.show()

```



```
1 !jupyter nbconvert --ClearMetadataPreprocessor.enabled=True \  
2 --ClearOutputPreprocessor.enabled=True \  
3 --to notebook --output cleaned.ipynb your_notebook.ipynb  
4
```




```
> jupyter nbconvert mynotebook.ipynb --stdout
```

PDF is generated via latex

```
> jupyter nbconvert mynotebook.ipynb --to pdf
```

You can get (and serve) a Reveal.js-powered slideshow

```
> jupyter nbconvert myslides.ipynb --to slides --post serve
```

Multiple notebooks can be given at the command line in a couple of different ways:

```
> jupyter nbconvert notebook*.ipynb
```

```
> jupyter nbconvert notebook1.ipynb notebook2.ipynb
```

or you can specify the notebooks list in a config file, containing::

```
c.NbConvertApp.notebooks = ["my_notebook.ipynb"]
```

```
> jupyter nbconvert --config mycfg.py
```

To see all available configurables, use `--help-all`.

```
1 !jupyter nbconvert --to html cleaned.ipynb
```

If a relative path is given, it must be a subdirectory of the