```
import re
from pathlib import Path
import numpy as np
import pandas as pd

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

```
/opt/conda/lib/python3.10/site-packages/scipy/__init__.py:146:
UserWarning: A NumPy version >=1.16.5 and <1.23.0 is required for this
version of SciPy (detected version 1.23.5
  warnings.warn(f"A NumPy version >={np_minversion} and
<{np_maxversion}"
```

```
import torch
from torchtext.vocab import build_vocab_from_iterator
!pip install transformers
from transformers import BertTokenizer
```

```
Requirement already satisfied: transformers in
/opt/conda/lib/python3.10/site-packages (4.28.1)
Requirement already satisfied: tokenizers!=0.11.3,<0.14,>=0.11.1 in
/opt/conda/lib/python3.10/site-packages (from transformers) (0.13.3)
Requirement already satisfied: requests in
/opt/conda/lib/python3.10/site-packages (from transformers) (2.28.2)
Requirement already satisfied: tqdm>=4.27 in
/opt/conda/lib/python3.10/site-packages (from transformers) (4.64.1)
Requirement already satisfied: filelock in
/opt/conda/lib/python3.10/site-packages (from transformers) (3.11.0)
Requirement already satisfied: pyyaml>=5.1 in
/opt/conda/lib/python3.10/site-packages (from transformers) (6.0)
Requirement already satisfied: regex!=2019.12.17 in
/opt/conda/lib/python3.10/site-packages (from transformers)
(2023.3.23)
Requirement already satisfied: numpy>=1.17 in
/opt/conda/lib/python3.10/site-packages (from transformers) (1.23.5)
Requirement already satisfied: packaging>=20.0 in
/opt/conda/lib/python3.10/site-packages (from transformers) (21.3)
Requirement already satisfied: huggingface-hub<1.0,>=0.11.0 in
/opt/conda/lib/python3.10/site-packages (from transformers) (0.13.4)
Requirement already satisfied: typing-extensions>=3.7.4.3 in
/opt/conda/lib/python3.10/site-packages (from huggingface-
hub<1.0,>=0.11.0->transformers) (4.5.0)
Requirement already satisfied: pyparsing!=3.0.5,>=2.0.2 in
/opt/conda/lib/python3.10/site-packages (from packaging>=20.0-
>transformers) (3.0.9)
Requirement already satisfied: charset-normalizer<4,>=2 in
/opt/conda/lib/python3.10/site-packages (from requests->transformers)
(2.1.1)
Requirement already satisfied: idna<4,>=2.5 in
/opt/conda/lib/python3.10/site-packages (from requests->transformers)
```

```
(3.4)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in
/opt/conda/lib/python3.10/site-packages (from requests->transformers)
(1.26.15)
Requirement already satisfied: certifi>=2017.4.17 in
/opt/conda/lib/python3.10/site-packages (from requests->transformers)
(2022.12.7)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
```

```python
from typing import Callable

from sklearn.metrics import accuracy_score,
precision_recall_fscore_support

from torch.utils.data import DataLoader, TensorDataset

from sklearn.model_selection import RepeatedStratifiedKFold,
train_test_split
from sklearn.preprocessing import LabelEncoder

import torch.nn as nn
from transformers import BertModel

def simplify_text(s):
    # очищаем текст от мусора
    s = re.sub(r"[^\w\s]", ' ', s)

    s = re.sub(r"\s+", '-', s)

    return s

dataset = Path("/kaggle/input/for-task") / "financial.json"


def read_dataset(threshold: int = 30, verbose: bool = False) ->
pd.DataFrame:

    data = pd.read_json(dataset)
    sub_data: pd.DataFrame = data["_source"].apply(pd.Series)
    data = pd.concat([data.drop(columns="_source"), sub_data], axis=1)
    if verbose:
        print(data.shape[0])

    # Осатвляем только  строки имеющие текст заявки
    data["complaint_what_happened"] =
data["complaint_what_happened"].map(lambda x: re.sub(r"XXXX|XX/XX/\
d{4}", "", x))
    filtered_data = data[data["complaint_what_happened"].str.len() !=
```

```
0]
    if verbose:
        print(filtered_data.shape[0])
    filtered_data =
filtered_data[~filtered_data["complaint_what_happened"].isnull()]
    if verbose:
        print(filtered_data.shape[0])
        print(f"Average character number in ticket body:
{filtered_data['complaint_what_happened'].str.len().mean():.2f}")

    #  ----
    null_prods = filtered_data["product"].isnull().sum()
    null_subs = filtered_data["sub_product"].isnull().sum()
    if verbose:
        print(f"Nan values in 'product': {null_prods}")
        print(f"Nan values in 'sub_product': {null_subs}")

    # ----
    if verbose:
        print("Fixing missing values ...")
    filtered_data["sub_product"] =
filtered_data["sub_product"].fillna(filtered_data["product"])

    null_prods = filtered_data["product"].isnull().sum()
    null_subs = filtered_data["sub_product"].isnull().sum()
    if verbose:
        print(f"Nan values in 'product': {null_prods}")
        print(f"Nan values in 'sub_product': {null_subs}")

    # ----
    keep = ["complaint_what_happened", "product", "sub_product"]
    filtered_data = filtered_data.loc[:, keep]
    filtered_data.columns = ["message", "label", "sub_label"]

    # удаляем дубликаты
    filtered_data = filtered_data.drop_duplicates(subset=["message"],
keep="first")
    filtered_data = filtered_data.dropna(axis=0)

    filtered_data.loc[:, "label"] =
filtered_data["label"].map(simplify_text)
    filtered_data = filtered_data.dropna(axis=0)
    filtered_data.loc[:, "sub_label"] =
filtered_data["sub_label"].map(simplify_text)
    filtered_data = filtered_data.dropna(axis=0)
    filtered_data["flattened_label"] = filtered_data["label"] + "_" +
filtered_data["sub_label"]
    filtered_data = filtered_data.reset_index(drop=True)
```

```
    # удаляем категроии с недостаточным числом записей
    c1 = filtered_data["label"].value_counts()
    filtered_data = filtered_data.replace(c1[c1 < threshold].index,
np.nan).dropna(axis=0)
    c2 = filtered_data["sub_label"].value_counts()
    filtered_data = filtered_data.replace(c2[c2 < threshold].index,
np.nan).dropna(axis=0)
    filtered_data = filtered_data.reset_index(drop=True)

    if verbose:
        print(f"Final dataset of size: {filtered_data.shape}")

print(filtered_data.columns.to_series().to_string(index=False))
        print(filtered_data.isnull().sum(axis=0))
        print(filtered_data.shape[0])
    return filtered_data

read_financial = read_dataset()
read_financial.head()
```

```
                                                message  \
0  Good morning my name is   and I appreciate it ...
1  I upgraded my   card in  and was told by the a...
2  Chase Card was reported on . However, fraudule...
3  On , while trying to book a     ticket, I came...
4  my grand son give me check for {$1600.00} i de...

                                                  label  \
0                                    Debt-collection
1                          Credit-card-or-prepaid-card
2  Credit-reporting-credit-repair-services-or-oth...
3  Credit-reporting-credit-repair-services-or-oth...
4                          Checking-or-savings-account

                                       sub_label  \
0                             Credit-card-debt
1  General-purpose-credit-card-or-charge-card
2              Other-personal-consumer-report
3                             Credit-reporting
4                             Checking-account

                                       flattened_label
0                   Debt-collection_Credit-card-debt
1  Credit-card-or-prepaid-card_General-purpose-cr...
2  Credit-reporting-credit-repair-services-or-oth...
3  Credit-reporting-credit-repair-services-or-oth...
4       Checking-or-savings-account_Checking-account
```

```
num_classes = read_financial.label.nunique()
num_classes
```

14

```
class_mapping = {
    'Bank-account-or-service': 'Banking',
    'Checking-or-savings-account': 'Banking',
    'Consumer-Loan': 'Loans',
    'Credit-card': 'Credit',
    'Credit-card-or-prepaid-card': 'Credit',
    'Credit-reporting': 'Credit',
    'Credit-reporting-credit-repair-services-or-other-personal-
consumer-reports': 'Credit',
    'Debt-collection': 'Debt',
    'Money-transfer-virtual-currency-or-money-service': 'Money',
    'Money-transfers': 'Money',
    'Mortgage': 'Loans',
    'Payday-loan-title-loan-or-personal-loan': 'Loans',
    'Student-loan': 'Loans',
    'Vehicle-loan-or-lease': 'Loans'
}

# Замена значений в столбце "label" с использованием словаря
соответствий
read_financial['label'] = read_financial['label'].map(class_mapping)

# Вывод измененного датафрейма
read_financial.head()
```

	message	label	\
0	Good morning my name is and I appreciate it ...	Debt	
1	I upgraded my card in and was told by the a...	Credit	
2	Chase Card was reported on . However, fraudule...	Credit	
3	On , while trying to book a ticket, I came...	Credit	
4	my grand son give me check for {$1600.00} i de...	Banking	

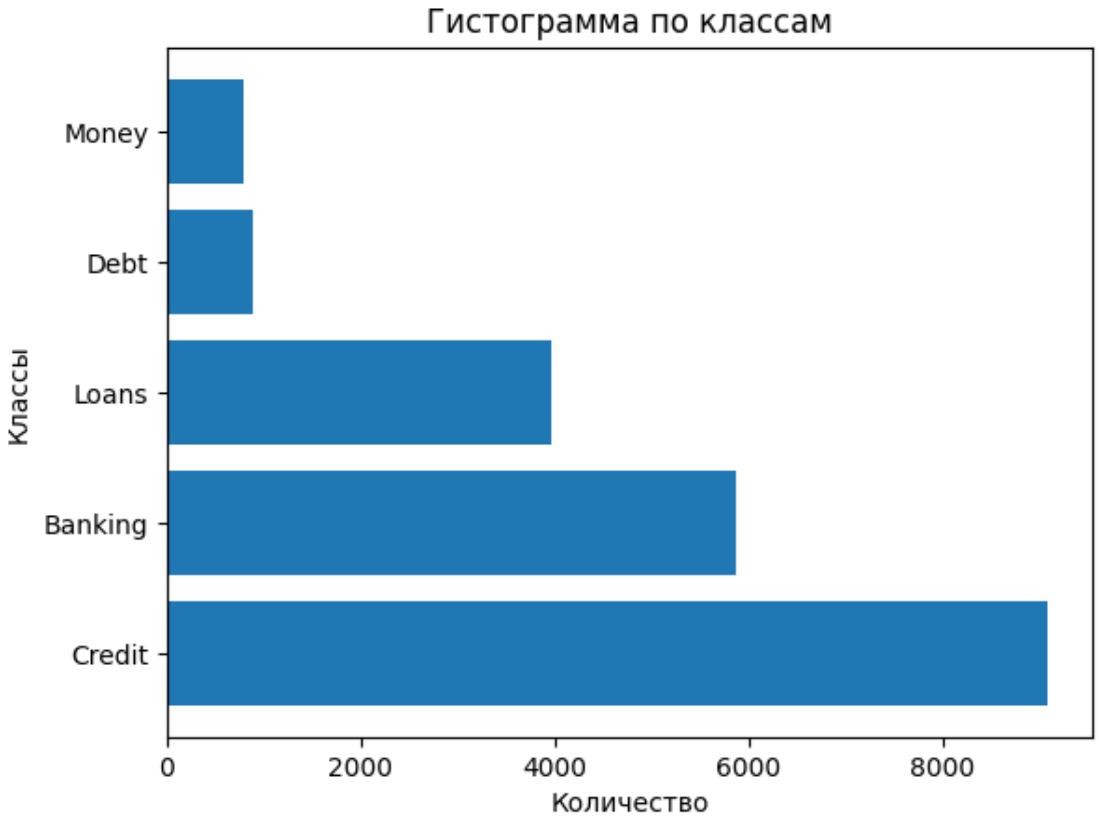
	sub_label	\
0	Credit-card-debt	
1	General-purpose-credit-card-or-charge-card	
2	Other-personal-consumer-report	
3	Credit-reporting	
4	Checking-account	

	flattened_label
0	Debt-collection_Credit-card-debt
1	Credit-card-or-prepaid-card_General-purpose-cr...
2	Credit-reporting-credit-repair-services-or-oth...
3	Credit-reporting-credit-repair-services-or-oth...
4	Checking-or-savings-account_Checking-account

```
num_classes = read_financial.label.nunique()
num_classes
```

5

```
# Подсчет количества значений в каждом классе
class_counts = read_financial['label'].value_counts()

# Сортировка классов по количеству в убывающем порядке
class_counts = class_counts.sort_values(ascending=False)

# Построение упорядоченной горизонтальной гистограммы
plt.barh(class_counts.index, class_counts.values)
plt.xlabel('Количество')
plt.ylabel('Классы')
plt.title('Гистограмма по классам')
plt.show()
```




```
def regex_fun(regex: str, value: str) -> Callable:
    return lambda x: re.sub(regex, value, x)


# def remove_linux_garbage(data):
#     """
#     Taken from: https://arxiv.org/abs/1807.02892
#     Linux data contains lots of garbage, e.g. memory addresses -
0000f800
```

```
#     """

#     def is_garbage(w):
#         return len(w) >= 7 and sum(c.isdigit() for c in w) >= 2

#     data = data.map(lambda s: ' '.join(map(lambda w: w if not
is_garbage(w) else ' ', s.split())))
#     return data


def text_cleanup(msg, remove_garbage: bool = False):
    msg = msg.map(regex_fun("\r", " "))
    msg = msg.map(regex_fun("\n", " "))

    msg = msg.map(regex_fun(r"http[s]?://(?:[a-zA-Z]|[0-9]|[$-_@.&+]|
[!*\(\),]|(?:%[0-9a-fA-F][0-9a-fA-F]))+", ""))

    msg = msg.map(regex_fun(r"(\w+)0x\w+", ""))

    return msg.map(str.lower)

# как выглядит очищенный текст
text_cleanup(read_financial.message)
```

```
0        good morning my name is   and i appreciate it ...
1        i upgraded my   card in  and was told by the a...
2        chase card was reported on . however, fraudule...
3        on , while trying to book a     ticket, i came...
4        my grand son give me check for {$1600.00} i de...
                              ...
20585    my husband passed away. chase bank put check o...
20586    after being a chase card customer for well ove...
20587    on wednesday, xx/xx/ i called chas, my   visa ...
20588    i am not familiar with  pay and did not unders...
20589    i have had flawless credit for 30 yrs. i've ha...
Name: message, Length: 20590, dtype: object
```

```
def split_dataset(dataframe, test_size=0.2, max_length=128):
    # Инициализация токенизатора BERT
    tokenizer = BertTokenizer.from_pretrained('bert-base-uncased')

    # Извлечение признаков и меток классов из датафрейма
    X = text_cleanup(dataframe["message"]).tolist()
    y = dataframe["label"].tolist()

    # Преобразование меток классов в числовые значения
    label_encoder = LabelEncoder()
    y = label_encoder.fit_transform(y)
    class_mapping = dict(zip(label_encoder.classes_,
label_encoder.transform(label_encoder.classes_)))
```

```
    print (class_mapping)
    # Токенизация текстовых данных
    X_tokenized = tokenizer.batch_encode_plus(
        X,
        add_special_tokens=True, # Добавление специальных токенов
[CLS] и [SEP]
        max_length=max_length, # Ограничение длины входных данных
        padding='max_length', # Добавление паддинга до максимальной
длины
        truncation=True, # Обрезание текста, если он превышает
максимальную длину
        return_attention_mask=True, # Генерация маски внимания
        return_tensors='pt' # Возвращение данных в виде PyTorch
тензоров
    )

    # Конвертация меток классов в тензор PyTorch
    y = torch.tensor(y)

    # Разбиение данных на обучающую и тестовую выборки
    X_train, X_test, y_train, y_test, attention_train, attention_test,
token_train, token_test = train_test_split(X_tokenized['input_ids'],
y, X_tokenized['attention_mask'], X_tokenized['token_type_ids'],
test_size=test_size, random_state=42)

    # Возвращение готовых для дообучения BERT данных
    return X_train, X_test, y_train, y_test, attention_train,
attention_test, token_train, token_test

X_train, X_test, y_train, y_test, attention_train, attention_test,
token_train, token_test = split_dataset(read_financial)
```


```
{"model_id":"cde4c81fb79a4ad198237b05e738ffaf","version_major":2,"vers
ion_minor":0}

{"model_id":"608da0e7ef714c30a22f975497c64d03","version_major":2,"vers
ion_minor":0}

{"model_id":"bc6ad639a4f64e4e8d97251cf913c2bd","version_major":2,"vers
ion_minor":0}
```


```
{'Banking': 0, 'Credit': 1, 'Debt': 2, 'Loans': 3, 'Money': 4}

# Создание датасетов PyTorch
train_dataset = TensorDataset(X_train, attention_train, token_train,
y_train)
test_dataset = TensorDataset(X_test, attention_test, token_test,
y_test)

# Создание DataLoader'ов для обучения и тестирования модели
batch_size = 64
```

```
train_loader = DataLoader(train_dataset, batch_size=batch_size,
shuffle=True)
test_loader = DataLoader(test_dataset, batch_size=batch_size)

class BertClassifier(nn.Module):
    def __init__(self, num_classes):
        super(BertClassifier, self).__init__()

        self.bert1 = BertModel.from_pretrained('bert-base-uncased')
        self.bert1.requires_grad_(False)  # Замораживаем веса

        self.bert2 = BertModel.from_pretrained('bert-base-uncased')
        self.bert2.requires_grad_(False)  # Замораживаем веса

        self.fc = nn.Linear(self.bert1.config.hidden_size +
self.bert2.config.hidden_size, num_classes)
        self.dropout = nn.Dropout(0.1)

    def forward(self, input_ids, attention_mask, token_train):
        pooled_output1 = self.bert1(input_ids=input_ids,
attention_mask=attention_mask, token_type_ids=token_train)[1]
        pooled_output2 = self.bert2(input_ids=input_ids,
attention_mask=attention_mask, token_type_ids=token_train)[1]

        combined_output = torch.cat((pooled_output1, pooled_output2),
dim=1)
        combined_output = self.dropout(combined_output)

        logits = self.fc(combined_output)
        return logits

model = BertClassifier(num_classes=num_classes)
```

{"model_id":"3fc8defee6644b49b045097068abacfd","version_major":2,"vers
ion_minor":0}

```
Some weights of the model checkpoint at bert-base-uncased were not
used when initializing BertModel:
['cls.predictions.transform.LayerNorm.bias',
'cls.predictions.transform.dense.bias', 'cls.seq_relationship.bias',
'cls.predictions.transform.dense.weight',
'cls.predictions.decoder.weight',
'cls.predictions.transform.LayerNorm.weight',
'cls.seq_relationship.weight', 'cls.predictions.bias']
- This IS expected if you are initializing BertModel from the
checkpoint of a model trained on another task or with another
architecture (e.g. initializing a BertForSequenceClassification model
from a BertForPreTraining model).
- This IS NOT expected if you are initializing BertModel from the
checkpoint of a model that you expect to be exactly identical
```

```
(initializing a BertForSequenceClassification model from a
BertForSequenceClassification model).
Some weights of the model checkpoint at bert-base-uncased were not
used when initializing BertModel:
['cls.predictions.transform.LayerNorm.bias',
'cls.predictions.transform.dense.bias', 'cls.seq_relationship.bias',
'cls.predictions.transform.dense.weight',
'cls.predictions.decoder.weight',
'cls.predictions.transform.LayerNorm.weight',
'cls.seq_relationship.weight', 'cls.predictions.bias']
- This IS expected if you are initializing BertModel from the
checkpoint of a model trained on another task or with another
architecture (e.g. initializing a BertForSequenceClassification model
from a BertForPreTraining model).
- This IS NOT expected if you are initializing BertModel from the
checkpoint of a model that you expect to be exactly identical
(initializing a BertForSequenceClassification model from a
BertForSequenceClassification model).
```

```
# Вычисление весов классов на основе их распределения в данных
class_counts = read_financial['label'].value_counts()
total_samples = len(read_financial)
class_weights = [total_samples / (class_counts[label] *
len(class_counts)) for label in sorted(class_counts.keys())]

# Преобразование весов классов в тензор
class_weights_tensor = torch.tensor(class_weights, dtype=torch.float)
class_weights_tensor = class_weights_tensor.to(device)
# Создание экземпляра функции потерь с учетом весов классов
criterion = nn.CrossEntropyLoss(weight=class_weights_tensor)
class_weights
```

```
[0.7016527517464645,
 0.45342435586875135,
 4.621773288439955,
 1.0388496468213926,
 5.252551020408164]
```

```
# Установка вычислительного устройства для обучения модели
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
print('Using device:', device)

if device.type == 'cuda':
    print(torch.cuda.get_device_name(0))
    print('Memory Usage:')
    print('Allocated:',
round(torch.cuda.memory_allocated(0)/1024**3,1), 'GB')
    print('Cached:   ', round(torch.cuda.memory_cached(0)/1024**3,1),
'GB')
```

```
model.to(device)

Using device: cuda
Tesla P100-PCIE-16GB
Memory Usage:
Allocated: 0.0 GB
Cached:    0.0 GB

/opt/conda/lib/python3.10/site-packages/torch/cuda/memory.py:416:
FutureWarning: torch.cuda.memory_cached has been renamed to
torch.cuda.memory_reserved
  warnings.warn(

BertClassifier(
  (bert1): BertModel(
    (embeddings): BertEmbeddings(
      (word_embeddings): Embedding(30522, 768, padding_idx=0)
      (position_embeddings): Embedding(512, 768)
      (token_type_embeddings): Embedding(2, 768)
      (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
      (dropout): Dropout(p=0.1, inplace=False)
    )
    (encoder): BertEncoder(
      (layer): ModuleList(
        (0-11): 12 x BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768,
bias=True)
              (key): Linear(in_features=768, out_features=768,
bias=True)
              (value): Linear(in_features=768, out_features=768,
bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768,
bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072,
bias=True)
            (intermediate_act_fn): GELUActivation()
          )
          (output): BertOutput(
```

```
            (dense): Linear(in_features=3072, out_features=768,
bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
      )
    )
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    )
  )
  (bert2): BertModel(
    (embeddings): BertEmbeddings(
      (word_embeddings): Embedding(30522, 768, padding_idx=0)
      (position_embeddings): Embedding(512, 768)
      (token_type_embeddings): Embedding(2, 768)
      (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
      (dropout): Dropout(p=0.1, inplace=False)
    )
    (encoder): BertEncoder(
      (layer): ModuleList(
        (0-11): 12 x BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768,
bias=True)
              (key): Linear(in_features=768, out_features=768,
bias=True)
              (value): Linear(in_features=768, out_features=768,
bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768,
bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072,
bias=True)
            (intermediate_act_fn): GELUActivation()
          )
          (output): BertOutput(
```

```
            (dense): Linear(in_features=3072, out_features=768,
bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12,
elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
      )
    )
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    )
  )
  (fc): Linear(in_features=1536, out_features=5, bias=True)
  (dropout): Dropout(p=0.1, inplace=False)
)

train_losses = []
test_losses = []

# device = torch.device ("cpu")
# model.to(device)

from torch.optim import AdamW
optimizer = AdamW(model.parameters(), lr=1e-4)
epochs = 5
for epoch in range(epochs):
    print("Epoch: " + str(epoch))
    # Обучение модели на тренировочном наборе
    train_loss = 0.0
    model.train()
    for batch_idx, (input_ids, attention_mask, token_train, labels) in
enumerate(train_loader):
        if batch_idx % 10 == 0:
          print("Batch: " + str(batch_idx))
        input_ids, attention_mask, token_train, labels =
input_ids.to(device), attention_mask.to(device),
token_train.to(device), labels.to(device)
        optimizer.zero_grad()
        outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train=token_train)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
        train_loss += loss.item()
    train_loss /= len(train_loader)
    train_losses.append(train_loss)

    # Оценка модели на тестовом наборе
    test_loss = 0.0
```

```
    model.eval()
    with torch.no_grad():
        for batch_idx, (input_ids, attention_mask, token_test, labels)
in enumerate(test_loader):
            input_ids, attention_mask, token_test, labels =
input_ids.to(device), attention_mask.to(device),
token_test.to(device), labels.to(device)
            outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train = token_test)
            loss = criterion(outputs, labels)
            test_loss += loss.item()
    test_loss /= len(test_loader)
    test_losses.append(test_loss)

    # Вывод информации о процессе обучения
    print('Epoch [{}/{}], Train Loss: {:.4f}, Test Loss:
{:.4f}'.format(epoch+1, epochs, train_loss, test_loss))
```

```
Epoch: 0
Batch: 0
Batch: 10
Batch: 20
Batch: 30
Batch: 40
Batch: 50
Batch: 60
Batch: 70
Batch: 80
Batch: 90
Batch: 100
Batch: 110
Batch: 120
Batch: 130
Batch: 140
Batch: 150
Batch: 160
Batch: 170
Batch: 180
Batch: 190
Batch: 200
Batch: 210
Batch: 220
Batch: 230
Batch: 240
Batch: 250
Epoch [1/12], Train Loss: 1.3174, Test Loss: 1.2763
Epoch: 1
Batch: 0
Batch: 10
Batch: 20
```

```
Batch: 30
Batch: 40
Batch: 50
Batch: 60
Batch: 70
Batch: 80
Batch: 90
Batch: 100
Batch: 110
Batch: 120
Batch: 130
Batch: 140
Batch: 150
Batch: 160
Batch: 170
Batch: 180
Batch: 190
Batch: 200
Batch: 210
Batch: 220
Batch: 230
Batch: 240
Batch: 250
Epoch [2/12], Train Loss: 1.3154, Test Loss: 1.2788
Epoch: 2
Batch: 0
Batch: 10
Batch: 20
Batch: 30
Batch: 40
Batch: 50
Batch: 60
Batch: 70
Batch: 80
Batch: 90
Batch: 100
Batch: 110
Batch: 120
Batch: 130
Batch: 140
Batch: 150
Batch: 160
Batch: 170
Batch: 180
Batch: 190
Batch: 200
Batch: 210
Batch: 220
Batch: 230
Batch: 240
```

```
Batch: 250
Epoch [3/12], Train Loss: 1.3093, Test Loss: 1.2755
Epoch: 3
Batch: 0
Batch: 10
Batch: 20
Batch: 30
Batch: 40
Batch: 50

---------------------------------------------------------------------------
-----
KeyboardInterrupt                         Traceback (most recent call
last)
Cell In[36], line 18
     16     loss.backward()
     17     optimizer.step()
---> 18     train_loss += loss.item()
     19 train_loss /= len(train_loader)
     20 train_losses.append(train_loss)

KeyboardInterrupt:
```

```python
model.dropout = nn.Dropout(0.7)
# layer1 = ['pooler.dense.', 'encoder.layer.11.', 'encoder.layer.10.',
'encoder.layer.9.']
pars1 = []
for name, param in model.bert2.named_parameters():
    pars1.append(param)

for name, param in model.bert1.named_parameters():
    pars1.append(param)

for param in pars1:
    param.requires_grad = True

from torch.optim import AdamW
optimizer = AdamW(model.parameters(), lr=1e-7)
epochs = 3
for epoch in range(epochs):
    print("Epoch: " + str(epoch))
    # Обучение модели на тренировочном наборе
    train_loss = 0.0
    model.train()
    for batch_idx, (input_ids, attention_mask, token_train, labels) in
enumerate(train_loader):
        if batch_idx % 10 == 0:
          print("Batch: " + str(batch_idx))
        input_ids, attention_mask, token_train, labels =
input_ids.to(device), attention_mask.to(device),
```

```
token_train.to(device), labels.to(device)
        optimizer.zero_grad()
        outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train=token_train)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
        train_loss += loss.item()
    train_loss /= len(train_loader)
    train_losses.append(train_loss)

    # Оценка модели на тестовом наборе
    test_loss = 0.0
    model.eval()
    with torch.no_grad():
        for batch_idx, (input_ids, attention_mask, token_test, labels)
in enumerate(test_loader):
            input_ids, attention_mask, token_test, labels =
input_ids.to(device), attention_mask.to(device),
token_test.to(device), labels.to(device)
            outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train = token_test)
            loss = criterion(outputs, labels)
            test_loss += loss.item()
    test_loss /= len(test_loader)
    test_losses.append(test_loss)

    # Вывод информации о процессе обучения
    print('Epoch [{}/{}], Train Loss: {:.4f}, Test Loss:
{:.4f}'.format(epoch+1, epochs, train_loss, test_loss))

for param in pars1:
    param.requires_grad = False
```

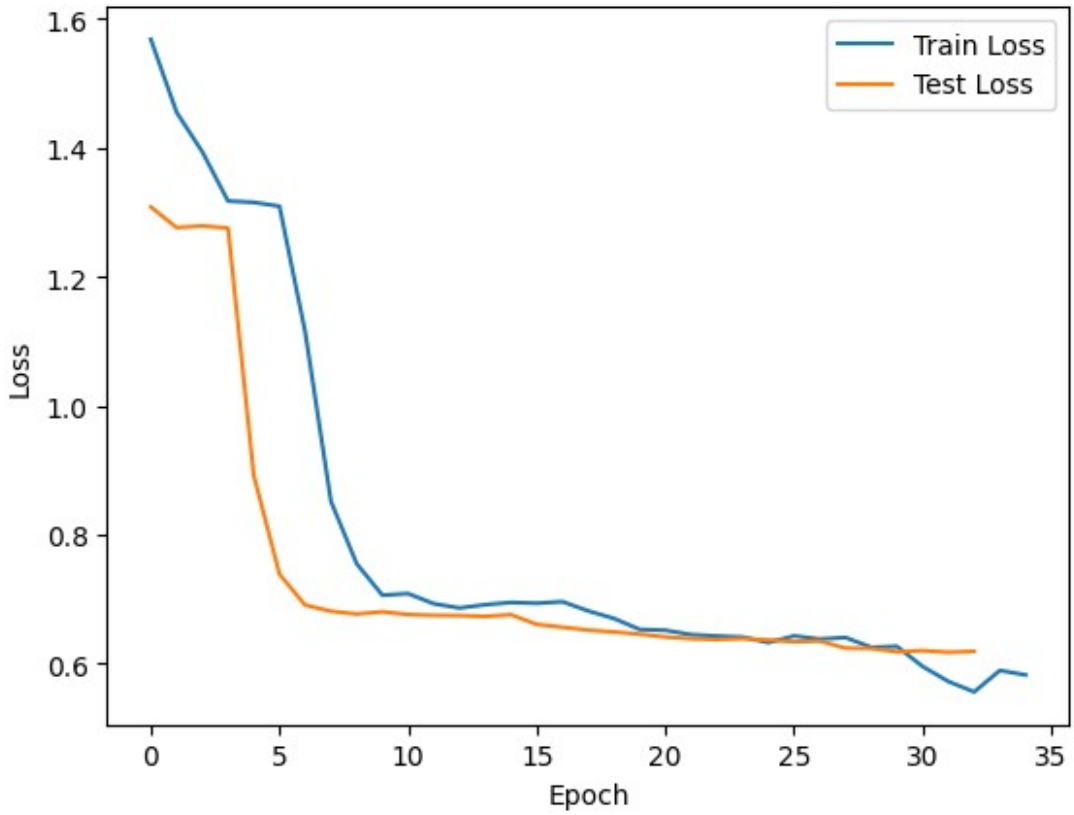
```
Epoch: 0
Batch: 0
Batch: 10
Batch: 20
Batch: 30
Batch: 40
Batch: 50
Batch: 60
Batch: 70
Batch: 80
Batch: 90
Batch: 100
Batch: 110
Batch: 120
Batch: 130
Batch: 140
```

```
Batch: 150
Batch: 160
Batch: 170
Batch: 180
Batch: 190
Batch: 200
Batch: 210
Batch: 220
Batch: 230
Batch: 240
Batch: 250
Epoch [1/3], Train Loss: 0.5890, Test Loss: 0.6172
Epoch: 1
Batch: 0
Batch: 10
Batch: 20
Batch: 30
Batch: 40
Batch: 50
Batch: 60
Batch: 70
Batch: 80
Batch: 90
Batch: 100
Batch: 110
Batch: 120
Batch: 130
Batch: 140
Batch: 150
Batch: 160
Batch: 170
Batch: 180
Batch: 190
Batch: 200
Batch: 210
Batch: 220
Batch: 230
Batch: 240
Batch: 250
Epoch [2/3], Train Loss: 0.5821, Test Loss: 0.6187
Epoch: 2
Batch: 0
Batch: 10
Batch: 20
Batch: 30

---------------------------------------------------------------------------
-----
KeyboardInterrupt                         Traceback (most recent call
last)
```

```
Cell In[49], line 28
     26 outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train=token_train)
     27 loss = criterion(outputs, labels)
---> 28 loss.backward()
     29 optimizer.step()
     30 train_loss += loss.item()

File /opt/conda/lib/python3.10/site-packages/torch/_tensor.py:487, in
Tensor.backward(self, gradient, retain_graph, create_graph, inputs)
    477 if has_torch_function_unary(self):
    478     return handle_torch_function(
    479         Tensor.backward,
    480         (self,),
   (...)
    485         inputs=inputs,
    486     )
--> 487 torch.autograd.backward(
    488     self, gradient, retain_graph, create_graph, inputs=inputs
    489 )

File
/opt/conda/lib/python3.10/site-packages/torch/autograd/__init__.py:200
, in backward(tensors, grad_tensors, retain_graph, create_graph,
grad_variables, inputs)
    195     retain_graph = create_graph
    197 # The reason we repeat same the comment below is that
    198 # some Python versions print out the first line of a multi-
line function
    199 # calls in the traceback and some print out the last line
--> 200 Variable._execution_engine.run_backward(  # Calls into the C++
engine to run the backward pass
    201     tensors, grad_tensors_, retain_graph, create_graph,
inputs,
    202     allow_unreachable=True, accumulate_grad=True)

KeyboardInterrupt:
```

```python
for name, param in model.bert1.named_parameters():
    if param.requires_grad == False:
        print(name)
```

```python
# Построение графика изменения значения функции потерь в процессе
обучения
plt.plot(train_losses, label='Train Loss')
plt.plot(test_losses, label='Test Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```




```
# Вычисление accuracy на тестовом наборе данных
model.eval()
with torch.no_grad():
    y_pred = []
    y_true = []
    for batch_idx, (input_ids, attention_mask, token_test, labels) in
enumerate(test_loader):
        input_ids, attention_mask, token_test, labels =
input_ids.to(device), attention_mask.to(device),
token_test.to(device), labels.to(device)
        outputs = model(input_ids=input_ids,
attention_mask=attention_mask, token_train=token_test)
        _, predicted = torch.max(outputs.data, 1)
        y_pred.extend(predicted.cpu().numpy())
        y_true.extend(labels.cpu().numpy())
accuracy = accuracy_score(y_true, y_pred)

# Вычисление precision, recall, f1-score на тестовом наборе данных
precision, recall, f1_score, _ =
precision_recall_fscore_support(y_true, y_pred, average='weighted')
print('Accuracy: {:.4f}, Precision: {:.4f}, Recall: {:.4f}, F1-score:
{:.4f}'.format(accuracy, precision, recall, f1_score))
```

```
Accuracy: 0.8043, Precision: 0.8423, Recall: 0.8043, F1-score: 0.8156
```

```python
# сохраняем параметры
torch.save(model.state_dict(), 'model_state_dict1.pth')

!pip install onnx
# сохраняем ONNX
model = BertClassifier(num_classes=num_classes)
model.load_state_dict(torch.load('model_state_dict1.pth'))

dummy_input_ids = torch.zeros((1, 128), dtype=torch.long)
dummy_attention_mask = torch.zeros((1, 128), dtype=torch.long)
dummy_token_id = torch.zeros((1, 128), dtype=torch.long)
torch.onnx.export(
    model,
    (dummy_input_ids, dummy_attention_mask, dummy_token_id),
    'bert_model.onnx',
    opset_version=11
)
```

```
Requirement already satisfied: onnx in /opt/conda/lib/python3.10/site-
packages (1.13.1)
Requirement already satisfied: typing-extensions>=3.6.2.1 in
/opt/conda/lib/python3.10/site-packages (from onnx) (4.5.0)
Requirement already satisfied: numpy>=1.16.6 in
/opt/conda/lib/python3.10/site-packages (from onnx) (1.23.5)
Requirement already satisfied: protobuf<4,>=3.20.2 in
/opt/conda/lib/python3.10/site-packages (from onnx) (3.20.3)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv

Some weights of the model checkpoint at bert-base-uncased were not
used when initializing BertModel:
['cls.predictions.transform.LayerNorm.bias',
'cls.predictions.transform.dense.bias', 'cls.seq_relationship.bias',
'cls.predictions.transform.dense.weight',
'cls.predictions.decoder.weight',
'cls.predictions.transform.LayerNorm.weight',
'cls.seq_relationship.weight', 'cls.predictions.bias']
- This IS expected if you are initializing BertModel from the
checkpoint of a model trained on another task or with another
architecture (e.g. initializing a BertForSequenceClassification model
from a BertForPreTraining model).
- This IS NOT expected if you are initializing BertModel from the
checkpoint of a model that you expect to be exactly identical
(initializing a BertForSequenceClassification model from a
BertForSequenceClassification model).
Some weights of the model checkpoint at bert-base-uncased were not
used when initializing BertModel:
['cls.predictions.transform.LayerNorm.bias',
'cls.predictions.transform.dense.bias', 'cls.seq_relationship.bias',
```

```
'cls.predictions.transform.dense.weight',
'cls.predictions.decoder.weight',
'cls.predictions.transform.LayerNorm.weight',
'cls.seq_relationship.weight', 'cls.predictions.bias']
- This IS expected if you are initializing BertModel from the
checkpoint of a model trained on another task or with another
architecture (e.g. initializing a BertForSequenceClassification model
from a BertForPreTraining model).
- This IS NOT expected if you are initializing BertModel from the
checkpoint of a model that you expect to be exactly identical
(initializing a BertForSequenceClassification model from a
BertForSequenceClassification model).

================ Diagnostic Run torch.onnx.export version 2.0.0
================
verbose: False, log level: Level.ERROR
======================= 0 NONE 0 NOTE 0 WARNING 0 ERROR
========================
```