Multiclass Text Classification with

Feed-forward Neural Networks and Word Embeddings

First, we will do some initialization.

In [9]:
```
import random
import torch
import numpy as np
import pandas as pd
from tqdm.notebook import tqdm

# enable tqdm in pandas
tqdm.pandas()

# set to True to use the gpu (if there is one available)
use_gpu = True

# select device
device = torch.device('cuda' if use_gpu and torch.cuda.is_available() else 'cpu')
print(f'device: {device.type}')

# random seed
seed = 1234

# set random seed
if seed is not None:
    print(f'random seed: {seed}')
    random.seed(seed)
    np.random.seed(seed)

    torch.manual_seed(seed)
```

```
device: cuda
random seed: 1234
```

Este código habilita tqdm para visualizar barras de progreso en operaciones de Pandas. Luego, define si se usará una GPU (use_gpu=True) y selecciona el dispositivo adecuado (cuda para GPU o cpu en caso contrario) mediante torch.device. También establece una semilla aleatoria (seed = 1234) para asegurar que siempre se usen los mismos datos para que las ejecuciones sean consistentes.

We will be using the AG's News Topic Classification Dataset.

It is stored in two CSV files: `train.csv` and `test.csv`, as well as a `classes.txt` that stores the labels of the classes to predict.

First, we will load the training dataset using pandas and take a quick look at how the data.

In [10]:
```
train_df = pd.read_csv('/kaggle/input/train-csv/train.csv', header=None)

train_df.columns = ['class index', 'title', 'description']

train_df
```

Out[10]:

	class index	title	description
0	Class Index	Title	Description
1	3	Wall St. Bears Claw Back Into the Black (Reuters)	Reuters - Short-sellers, Wall Street's dwindli...
2	3	Carlyle Looks Toward Commercial Aerospace (Reu...	Reuters - Private investment firm Carlyle Grou...
3	3	Oil and Economy Cloud Stocks' Outlook (Reuters)	Reuters - Soaring crude prices plus worries\ab...
4	3	Iraq Halts Oil Exports from Main Southern Pipe...	Reuters - Authorities have halted oil export\f...
...	...	...	...
119996	1	Pakistan's Musharraf Says Won't Quit as Army C...	KARACHI (Reuters) - Pakistani President Perve...
119997	2	Renteria signing a top-shelf deal	Red Sox general manager Theo Epstein acknowled...
119998	2	Saban not going to Dolphins yet	The Miami Dolphins will put their courtship of...
119999	2	Today's NFL games	PITTSBURGH at NY GIANTS Time: 1:30 p.m. Line: ...
120000	2	Nets get Carter from Raptors	INDIANAPOLIS -- All-Star Vince Carter was trad...

120001 rows × 3 columns

The dataset consists of 120,000 examples, each consisting of a class index, a title, and a description.

The class labels are distributed in a separated file. We will add the labels to the dataset so that we can interpret the data more easily. Note that the label indexes are one-based, so we need to subtract one to retrieve them from the list.

In [11]:

```
labels = open('/kaggle/input/classes-txt/classes.txt').read().splitlines()
train_df = train_df.drop(0).reset_index(drop=True)
train_df['class index'] = train_df['class index'].astype(int)
classes = train_df['class index'].map(lambda i: labels[i-1])
train_df.insert(1, 'class', classes)
train_df
```

Out[11]:

	class index	class	title	description
0	3	Business	Wall St. Bears Claw Back Into the Black (Reuters)	Reuters - Short-sellers, Wall Street's dwindli...
1	3	Business	Carlyle Looks Toward Commercial Aerospace (Reu...	Reuters - Private investment firm Carlyle Grou...
2	3	Business	Oil and Economy Cloud Stocks' Outlook (Reuters)	Reuters - Soaring crude prices plus worries\ab...
3	3	Business	Iraq Halts Oil Exports from Main Southern Pipe...	Reuters - Authorities have halted oil export\f...
4	3	Business	Oil prices soar to all-time record, posing new...	AFP - Tearaway world oil prices, toppling reco...
...	...	...	...	...
119995	1	World	Pakistan's Musharraf Says Won't Quit as Army C...	KARACHI (Reuters) - Pakistani President Perve...
119996	2	Sports	Renteria signing a top-shelf deal	Red Sox general manager Theo Epstein acknowled...
119997	2	Sports	Saban not going to Dolphins yet	The Miami Dolphins will put their courtship of...
119998	2	Sports	Today's NFL games	PITTSBURGH at NY GIANTS Time: 1:30 p.m. Line: ...
119999	2	Sports	Nets get Carter from Raptors	INDIANAPOLIS -- All-Star Vince Carter was trad...

120000 rows × 4 columns

Let's inspect how balanced our examples are by using a bar plot.

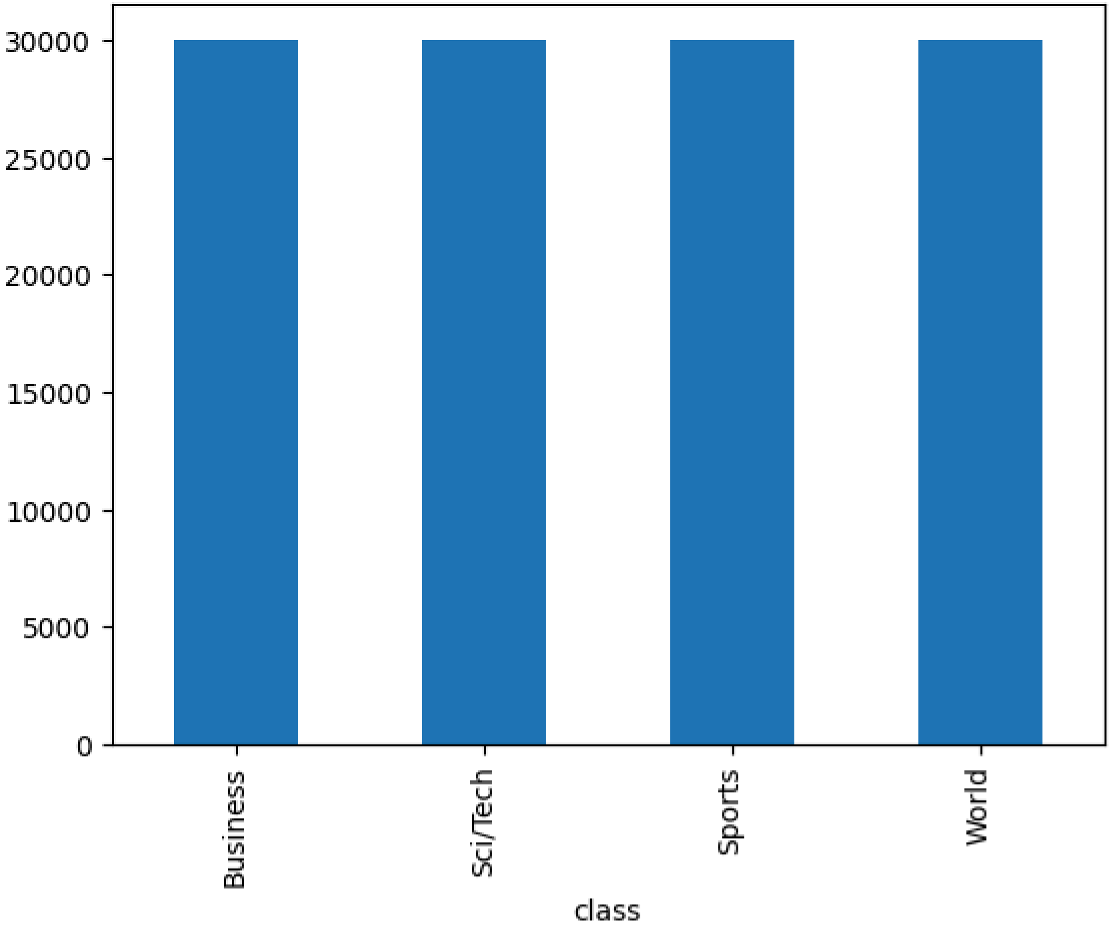
In [12]:

```
pd.value_counts(train_df['class']).plot.bar()
```

```
/tmp/ipykernel_30/1245903889.py:1: FutureWarning: pandas.value_counts is deprecated a
nd will be removed in a future version. Use pd.Series(obj).value_counts() instead.
  pd.value_counts(train_df['class']).plot.bar()
```

Out[12]:

```
<Axes: xlabel='class'>
```



The classes are evenly distributed. That's great!

However, the text contains some spurious backslashes in some parts of the text.

They are meant to represent newlines in the original text.

An example can be seen below, between the words "dwindling" and "band".

In [13]:
```
print(train_df.loc[0, 'description'])
```

```
Reuters - Short-sellers, Wall Street's dwindling\band of ultra-cynics, are seeing gre
en again.
```

We will replace the backslashes with spaces on the whole column using pandas replace method.

In [14]:
```
train_df['text'] = train_df['title'].str.lower() + " " + train_df['description'].str.l

train_df['text'] = train_df['text'].str.replace('\\', ' ', regex=False)

train_df
```

Out[14]:

	class index	class	title	description	text
0	3	Business	Wall St. Bears Claw Back Into the Black (Reuters)	Reuters - Short-sellers, Wall Street's dwindli...	wall st. bears claw back into the black (reute...
1	3	Business	Carlyle Looks Toward Commercial Aerospace (Reu...	Reuters - Private investment firm Carlyle Grou...	carlyle looks toward commercial aerospace (reu...
2	3	Business	Oil and Economy Cloud Stocks' Outlook (Reuters)	Reuters - Soaring crude prices plus worries\ab...	oil and economy cloud stocks' outlook (reuters...
3	3	Business	Iraq Halts Oil Exports from Main Southern Pipe...	Reuters - Authorities have halted oil export\f...	iraq halts oil exports from main southern pipe...
4	3	Business	Oil prices soar to all-time record, posing new...	AFP - Tearaway world oil prices, toppling reco...	oil prices soar to all-time record, posing new...
...	...	...	...	...	...
119995	1	World	Pakistan's Musharraf Says Won't Quit as Army C...	KARACHI (Reuters) - Pakistani President Perve...	pakistan's musharraf says won't quit as army c...
119996	2	Sports	Renteria signing a top-shelf deal	Red Sox general manager Theo Epstein acknowled...	renteria signing a top-shelf deal red sox gene...
119997	2	Sports	Saban not going to Dolphins yet	The Miami Dolphins will put their courtship of...	saban not going to dolphins yet the miami dolp...
119998	2	Sports	Today's NFL games	PITTSBURGH at NY GIANTS Time: 1:30 p.m. Line: ...	today's nfl games pittsburgh at ny giants time...
119999	2	Sports	Nets get Carter from Raptors	INDIANAPOLIS -- All-Star Vince Carter was trad...	nets get carter from raptors indianapolis -- a...

120000 rows × 5 columns

Crea una nueva columna text que combina el título y la descripción en minúsculas, ayudando a normalizar los datos para la tarea de procesamiento de lenguaje natural.

Now we will proceed to tokenize the title and description columns using NLTK's word_tokenize().

We will add a new column to our dataframe with the list of tokens.

In [15]:

```python
from nltk.tokenize import word_tokenize


train_df['tokens'] = train_df['text'].progress_map(word_tokenize)

train_df
```

```
  0%|          | 0/120000 [00:00<?, ?it/s]
```

Out[15]:

	class index	class	title	description	text	tokens
0	3	Business	Wall St. Bears Claw Back Into the Black (Reuters)	Reuters - Short-sellers, Wall Street's dwindli...	wall st. bears claw back into the black (reute...	[wall, st., bears, claw, back, into, the, blac...
1	3	Business	Carlyle Looks Toward Commercial Aerospace (Reu...	Reuters - Private investment firm Carlyle Grou...	carlyle looks toward commercial aerospace (reu...	[carlyle, looks, toward, commercial, aerospace...
2	3	Business	Oil and Economy Cloud Stocks' Outlook (Reuters)	Reuters - Soaring crude prices plus worries\ab...	oil and economy cloud stocks' outlook (reuters...	[oil, and, economy, cloud, stocks, ', outlook,...
3	3	Business	Iraq Halts Oil Exports from Main Southern Pipe...	Reuters - Authorities have halted oil export\f...	iraq halts oil exports from main southern pipe...	[iraq, halts, oil, exports, from, main, southe...
4	3	Business	Oil prices soar to all-time record, posing new...	AFP - Tearaway world oil prices, toppling reco...	oil prices soar to all-time record, posing new...	[oil, prices, soar, to, all-time, record, ,, p...
...	...	...	...	...	...	...
119995	1	World	Pakistan's Musharraf Says Won't Quit as Army C...	KARACHI (Reuters) - Pakistani President Perve...	pakistan's musharraf says won't quit as army c...	[pakistan, 's, musharraf, says, wo, n't, quit,...
119996	2	Sports	Renteria signing a top-shelf deal	Red Sox general manager Theo Epstein acknowled...	renteria signing a top-shelf deal red sox gene...	[renteria, signing, a, top-shelf, deal, red, s...
119997	2	Sports	Saban not going to Dolphins yet	The Miami Dolphins will put their courtship of...	saban not going to dolphins yet the miami dolp...	[saban, not, going, to, dolphins, yet, the, mi...
119998	2	Sports	Today's NFL games	PITTSBURGH at NY GIANTS Time: 1:30 p.m. Line: ...	today's nfl games pittsburgh at ny giants time...	[today, 's, nfl, games, pittsburgh, at, ny, gi...
119999	2	Sports	Nets get Carter from Raptors	INDIANAPOLIS -- All-Star Vince Carter was trad...	nets get carter from raptors indianapolis -- a...	[nets, get, carter, from, raptors, indianapoli...

120000 rows × 6 columns

Este código usa word_tokenize para dividir el texto en palabras, que serían los tokens. Esto se aplica a cada fila de la columna text en train_df, creando una nueva columna tokens que contiene listas de palabras tokenizadas para cada texto. Igualmente, la función

progress_map muestra el progreso de la operación gracias a tqdm, lo cual es útil para saber cuánto tiempo resta en el procesamiento de datos largos.

Now we will load the GloVe word embeddings.

In [16]:

```
from gensim.models import KeyedVectors
glove = KeyedVectors.load_word2vec_format('/kaggle/input/glove-txt/glove.6B.300d.txt',
glove.vectors.shape
```

Out[16]:

```
(400000, 300)
```

Se importa los embeedings preentrenados

The word embeddings have been pretrained in a different corpus, so it would be a good idea to estimate how good our tokenization matches the GloVe vocabulary.

In [17]:

```
from collections import Counter
def count_unknown_words(data, vocabulary):
    counter = Counter()
    for row in tqdm(data):
        counter.update(tok for tok in row if tok not in vocabulary)
    return counter
# find out how many times each unknown token occurrs in the corpus
c = count_unknown_words(train_df['tokens'], glove.key_to_index)
# find the total number of tokens in the corpus
total_tokens = train_df['tokens'].map(len).sum()
# find some statistics about occurrences of unknown tokens
unk_tokens = sum(c.values())
percent_unk = unk_tokens / total_tokens
distinct_tokens = len(list(c))
print(f'total number of tokens: {total_tokens:,}')
print(f'number of unknown tokens: {unk_tokens:,}')
print(f'number of distinct unknown tokens: {distinct_tokens:,}')
print(f'percentage of unkown tokens: {percent_unk:.2%}')
print('top 50 unknown words:')
for token, n in c.most_common(10):
    print(f'\t{n}\t{token}')
```

```
  0%|          | 0/120000 [00:00<?, ?it/s]
total number of tokens: 5,273,096
number of unknown tokens: 66,008
number of distinct unknown tokens: 24,792
percentage of unkown tokens: 1.25%
top 50 unknown words:
        2984    /b
        2119    href=
        2117    /a
        1813    //www.investor.reuters.com/fullquote.aspx
        1813    target=/stocks/quickinfo/fullquote
        537     /p
        510     newsfactor
        471     cbs.mw
        431     color=
        417     /font
```

Este código evalúa qué tan bien el vocabulario de los embeddings de GloVe cubre el conjunto de datos actual, identificando las palabras que no están presentes en el vocabulario de GloVe y calculando su frecuencia. Primero, la función count_unknown_words recorre cada token del conjunto de datos y cuenta aquellos que no están en GloVe. Luego, se ejecuta sobre la columna de tokens en los datos de entrenamiento y se sacan datos importantes (estadísticos). Finalmente, se imprimen estos datos junto con los 10 tokens desconocidos más comunes y sus frecuencias.

Glove embeddings seem to have a good coverage on this dataset -- only 1.25% of the tokens in the dataset are unknown, i.e., don't appear in the GloVe vocabulary.

Still, we will need a way to handle these unknown tokens.

Our approach will be to add a new embedding to GloVe that will be used to represent them.

This new embedding will be initialized as the average of all the GloVe embeddings.

We will also add another embedding, this one initialized to zeros, that will be used to pad the sequences of tokens so that they all have the same length. This will be useful when we train with mini-batches.

In [18]:

```
# string values corresponding to the new embeddings

unk_tok = '[UNK]'

pad_tok = '[PAD]'


# initialize the new embedding values

unk_emb = glove.vectors.mean(axis=0)

pad_emb = np.zeros(300)
```

```
# add new embeddings to glove

glove.add_vectors([unk_tok, pad_tok], [unk_emb, pad_emb])



# get token ids corresponding to the new embeddings

unk_id = glove.key_to_index[unk_tok]

pad_id = glove.key_to_index[pad_tok]



unk_id, pad_id
```

Out[18]:

```
(400000, 400001)
```

Aquí se añaden tokens al vocabulario de GloVe para mejorar como se usan palabras desconocidas y secuencias de longitud variable en el modelo. Primero, se definen dos nuevos tokens: [UNK] para palabras desconocidas y [PAD] para rellenar secuencias. Luego, se crean sus vectores: [UNK] se inicializa como el promedio de todos los vectores de GloVe, dandole valor a las palabras fuera del vocabulario, y [PAD] se establece en un vector de ceros. Estos nuevos vectores se añaden al vocabulario de GloVe, y se recuperan los IDs de [UNK] y [PAD] para meterlos en las secuencias de entrada del modelo.

In [19]:

```
from sklearn.model_selection import train_test_split


train_df, dev_df = train_test_split(train_df, train_size=0.8)

train_df.reset_index(inplace=True)

dev_df.reset_index(inplace=True)
```

Se dividen los datos de entrenamiento

We will now add a new column to our dataframe that will contain the padded sequences of token ids.

In [20]:

```
threshold = 10

tokens = train_df['tokens'].explode().value_counts()

vocabulary = set(tokens[tokens > threshold].index.tolist())

print(f'vocabulary size: {len(vocabulary):,}')
```

```
vocabulary size: 17,441
```

Como en el nb pasado, se aceptan los tokens que son más grandes del umbral 10.

In [21]:

```
# find the length of the longest list of tokens
```

```
max_tokens = train_df['tokens'].map(len).max()
# return unk_id for infrequent tokens too
def get_id(tok):
    if tok in vocabulary:
        return glove.key_to_index.get(tok, unk_id)
    else:
        return unk_id
# function that gets a list of tokens and returns a list of token ids,
# with padding added accordingly
def token_ids(tokens):
    tok_ids = [get_id(tok) for tok in tokens]
    pad_len = max_tokens - len(tok_ids)
    return tok_ids + [pad_id] * pad_len
# add new column to the dataframe
train_df['token ids'] = train_df['tokens'].progress_map(token_ids)
train_df
```

```
  0%|          | 0/96000 [00:00<?, ?it/s]
```

Out[21]:

	index	class index	class	title	description	text	tokens	token ids
0	9116	1	World	Najaf's Residents Feel Trapped in Battle (AP)	AP - For nearly three weeks, Amer al-Jamali ha...	najaf's residents feel trapped in battle (ap) ...	[najaf, 's, residents, feel, trapped, in, batt...	[10709, 9, 1048, 998, 4799, 6, 903, 23, 1582, ...
1	99831	3	Business	U.S. FDA Adds Restrictions to Acne Drug	WASHINGTON (Reuters) - Roche's acne drug Accu...	u.s. fda adds restrictions to acne drug washi...	[u.s., fda, adds, restrictions, to, acne, drug...	[99, 5584, 2144, 3252, 4, 400000, 780, 289, 23...
2	10663	3	Business	Smithfield Foods Profit More Than Doubles	Smithfield Foods Inc. (SFD.N: Quote, Profile, ...	smithfield foods profit more than doubles smit...	[smithfield, foods, profit, more, than, double...	[34026, 5008, 1269, 56, 73, 4229, 34026, 5008,...
3	73175	4	Sci/Tech	PluggedIn: The OQO Is Not Just Another Handhel...	SAN FRANCISCO (Reuters) - A full-fledged Wind...	pluggedin: the oqo is not just another handhel...	[pluggedin, :, the, oqo, is, not, just, anothe...	[400000, 45, 0, 293697, 14, 36, 120, 170, 2099...
4	104494	4	Sci/Tech	IBM invigorates LTO tape storage	LTO (linear tape open)-based drives are invigo...	ibm invigorates lto tape storage lto (linear t...	[ibm, invigorates, lto, tape, storage, lto, (,...	[5199, 400000, 400000, 4143, 4418, 400000, 23,...
...	...	...	...	...	...	...	...	...
95995	89460	1	World	Bush, Blair See Hope for Palestinian State (AP)	AP - As Yasser Arafat was buried, President Bu...	bush, blair see hope for palestinian state (ap...	[bush, ,, blair, see, hope, for, palestinian, ...	[272, 1, 2356, 253, 824, 10, 463, 92, 23, 1582...
95996	60620	1	World	Ex-Soldiers Vow to Bring Order to Haiti Capital	Ex-soldiers who helped topple former President...	ex-soldiers vow to bring order to haiti capita...	[ex-soldiers, vow, to, bring, order, to, haiti...	[223970, 12887, 4, 938, 460, 4, 3836, 351, 223...
95997	34086	1	World	Musharraf says U.S. must address root of terro...	Reuters - The United States could lose its war...	musharraf says u.s. must address root of terro...	[musharraf, says, u.s., must, address, root, o...	[3820, 210, 99, 390, 1476, 5440, 3, 1291, 23, ...

	index	class index	class	title	description	text	tokens	token ids
95998	58067	1	World	Nuclear materials #39;vanish #39; in Iraq	Equipment and materials that could be used to ...	nuclear materials #39;vanish #39; in iraq equ...	[nuclear, materials, #, 39, ;, vanish, #, 39, ...	[490, 2176, 2749, 3403, 89, 25736, 2749, 3403,...
95999	92975	4	Sci/Tech	In Brief: Bowstreet unveils pre-packaged porta...	Bowstreet this week launched its Enterprise Po...	in brief: bowstreet unveils pre-packaged porta...	[in, brief, :, bowstreet, unveils, pre-package...	[6, 2461, 45, 400000, 20465, 400000, 12174, 83...

96000 rows × 8 columns

Este código convierte cada secuencia de tokens en una lista de IDs, agregando relleno para que todas tengan la misma longitud. Primero, calcula la longitud máxima de los tokens (max_tokens). Luego, define funciones que asignan IDs a los tokens o el ID de desconocido (unk_id) si no están en el vocabulario, y rellenan con el ID de padding (pad_id). Finalmente, añade una columna token ids al DataFrame con las secuencias procesadas y con relleno uniforme.

In [22]:

```
max_tokens = dev_df['tokens'].map(len).max()

dev_df['token ids'] = dev_df['tokens'].progress_map(token_ids)

dev_df
```

```
  0%|          | 0/24000 [00:00<?, ?it/s]
```

Out[22]:

	index	class index	class	title	description	text	tokens	token ids
0	60974	1	World	Sharon Accepts Plan to Reduce Gaza Army Operat...	Israeli Prime Minister Ariel Sharon accepted a...	sharon accepts plan to reduce gaza army operat...	[sharon, accepts, plan, to, reduce, gaza, army...	[2548, 9889, 394, 4, 1680, 1166, 330, 957, 1, ...
1	50391	4	Sci/Tech	Internet Key Battleground in Wildlife Crime Fight	Why trawl through a sweaty illegal\wildlife ma...	internet key battleground in wildlife crime fi...	[internet, key, battleground, in, wildlife, cr...	[925, 638, 14944, 6, 4446, 1340, 838, 738, 400...
2	9307	3	Business	July Durable Good Orders Rise 1.7 Percent	America's factories saw orders for costly manu...	july durable good orders rise 1.7 percent amer...	[july, durable, good, orders, rise, 1.7, perce...	[375, 10699, 219, 1949, 1027, 6262, 72, 453, 9...
3	35221	3	Business	Growing Signs of a Slowing on Wall Street	all Street #39;s earnings growth, fueled by tw...	growing signs of a slowing on wall street all ...	[growing, signs, of, a, slowing, on, wall, str...	[988, 1867, 3, 7, 6515, 13, 1015, 491, 64, 491...
4	40081	1	World	The New Faces of Reality TV	The introduction of children to the genre was ...	the new faces of reality tv the introduction o...	[the, new, faces, of, reality, tv, the, introd...	[0, 50, 1919, 3, 2532, 816, 0, 4344, 3, 271, 4...
...	...	...	...	...	...	...	...	...
23995	49572	1	World	Iraqi Kidnappers Release 2 Indonesian Women	Two Indonesian women held hostage for several ...	iraqi kidnappers release 2 indonesian women tw...	[iraqi, kidnappers, release, 2, indonesian, wo...	[710, 9349, 713, 232, 2656, 266, 55, 2656, 266...
23996	40409	4	Sci/Tech	Big Wi-Fi Project for Philadelphia	What would Benjamin Franklin say? Philadelphia...	big wi-fi project for philadelphia what would ...	[big, wi-fi, project, for, philadelphia, what,...	[365, 39300, 716, 10, 2201, 102, 54,

	index	class index	class	title	description	text	tokens	token ids
								4067, 503...
23997	70470	2	Sports	Owen scores again	Michael Owen scored the winner for Real Madrid...	owen scores again michael owen scored the winn...	[owen, scores, again, michael, owen, scored, t...	[7116, 2776, 378, 785, 7116, 878, 0, 1364, 10,...
23998	7941	4	Sci/Tech	US Online Retail Sales Expected To Double In S...	Online retail sales in the US are expected to ...	us online retail sales expected to double in s...	[us, online, retail, sales, expected, to, doub...	[95, 1292, 2645, 526, 287, 4, 1278, 6, 228, 82...
23999	42303	1	World	Egyptian holding company says it has heard fou...	Egypt said Tuesday that Iraqi kidnappers had f...	egyptian holding company says it has heard fou...	[egyptian, holding, company, says, it, has, he...	[2434, 1383, 128, 210, 20, 31, 1435, 133, 2434...

24000 rows × 8 columns

Now we will get a numpy 2-dimensional array corresponding to the token ids,

and a 1-dimensional array with the gold classes. Note that the classes are one-based (i.e., they start at one),

but we need them to be zero-based, so we need to subtract one from this array.

In [23]:
```
from torch.utils.data import Dataset

class MyDataset(Dataset):
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __len__(self):
        return len(self.y)
    def __getitem__(self, index):
        x = torch.tensor(self.x[index])
        y = torch.tensor(self.y[index])
        return x, y
```

Este código define una clase MyDataset para usar los datos en PyTorch. La clase guarda las entradas (x) y etiquetas (y), y define dos métodos clave: len, que devuelve el número total de ejemplos, y getitem, que convierte cada entrada y su etiqueta en tensores de PyTorch.

Next, we construct our PyTorch model, which is a feed-forward neural network with two layers:

In [24]:

```
from torch import nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self, vectors, pad_id, hidden_dim, output_dim, dropout):
        super().__init__()
        # embeddings must be a tensor
        if not torch.is_tensor(vectors):
            vectors = torch.tensor(vectors)
        # keep padding id
        self.padding_idx = pad_id
        # embedding layer
        self.embs = nn.Embedding.from_pretrained(vectors, padding_idx=pad_id)
        # feedforward layers
        self.layers = nn.Sequential(
            nn.Dropout(dropout),
            nn.Linear(vectors.shape[1], hidden_dim),
            nn.ReLU(),
            nn.Dropout(dropout),
            nn.Linear(hidden_dim, output_dim),
        )
    def forward(self, x):
        # get boolean array with padding elements set to false
        not_padding = torch.isin(x, self.padding_idx, invert=True)
        # get lengths of examples (excluding padding)
        lengths = torch.count_nonzero(not_padding, axis=1)
        # get embeddings
        x = self.embs(x)
        # calculate means
        x = x.sum(dim=1) / lengths.unsqueeze(dim=1)
        # pass to rest of the model
        output = self.layers(x)
        # calculate softmax if we're not in training mode
        #if not self.training:
        #    output = F.softmax(output, dim=1)
        return output
```

Este código define una clase Model en PyTorch para clasificar texto utilizando embeddings preentrenados y capas densas. Primero, en la inicialización, convierte vectors a un tensor si es necesario y lo carga en una capa de embeddings (self.embs), donde no se toma en cuenta a los tokens de padding (pad_id). Luego, agrega capas densas, que incluyen Dropout para regularización, una capa lineal que reduce la dimensión de los embeddings, una activación ReLU y una capa final que genera la salida con la cantidad de clases (output_dim). En la propagación hacia adelante, el modelo crea una máscara para ignorar los tokens de padding y calcula la longitud real de cada secuencia. Luego, obtiene los embeddings de cada token y promedia los valores ignorando el padding, pasando el resultado por las capas densas para producir la salida final. Este modelo maneja el padding y los embeddings preentrenados para clasificar secuencias de texto.

Next, we implement the training procedure. We compute the loss and accuracy on the development partition after each epoch.

In [25]:

```
from torch import optim
from torch.utils.data import DataLoader
from sklearn.metrics import accuracy_score
```

```
# hyperparameters
lr = 1e-3
weight_decay = 0
batch_size = 500
shuffle = True
n_epochs = 5
hidden_dim = 50
output_dim = len(labels)
dropout = 0.1
vectors = glove.vectors

# initialize the model, loss function, optimizer, and data-loader
model = Model(vectors, pad_id, hidden_dim, output_dim, dropout).to(device)
loss_func = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=lr, weight_decay=weight_decay)
train_ds = MyDataset(train_df['token ids'], train_df['class index'] - 1)
train_dl = DataLoader(train_ds, batch_size=batch_size, shuffle=shuffle)
dev_ds = MyDataset(dev_df['token ids'], dev_df['class index'] - 1)
dev_dl = DataLoader(dev_ds, batch_size=batch_size, shuffle=shuffle)

train_loss = []
train_acc = []

dev_loss = []
dev_acc = []

# train the model
for epoch in range(n_epochs):
    losses = []
    gold = []
```

```
pred = []
model.train()
for X, y_true in tqdm(train_dl, desc=f'epoch {epoch+1} (train)'):
    # clear gradients
    model.zero_grad()
    # send batch to right device
    X = X.to(device)
    y_true = y_true.to(device)
    # predict label scores
    y_pred = model(X)
    # compute loss
    loss = loss_func(y_pred, y_true)
    # accumulate for plotting
    losses.append(loss.detach().cpu().item())
    gold.append(y_true.detach().cpu().numpy())
    pred.append(np.argmax(y_pred.detach().cpu().numpy(), axis=1))
    # backpropagate
    loss.backward()
    # optimize model parameters
    optimizer.step()
train_loss.append(np.mean(losses))
train_acc.append(accuracy_score(np.concatenate(gold), np.concatenate(pred)))

model.eval()
with torch.no_grad():
    losses = []
    gold = []
    pred = []
    for X, y_true in tqdm(dev_dl, desc=f'epoch {epoch+1} (dev)'):
        X = X.to(device)
```

```
            y_true = y_true.to(device)

            y_pred = model(X)

            loss = loss_func(y_pred, y_true)

            losses.append(loss.cpu().item())

            gold.append(y_true.cpu().numpy())

            pred.append(np.argmax(y_pred.cpu().numpy(), axis=1))

        dev_loss.append(np.mean(losses))

        dev_acc.append(accuracy_score(np.concatenate(gold), np.concatenate(pred)))
```

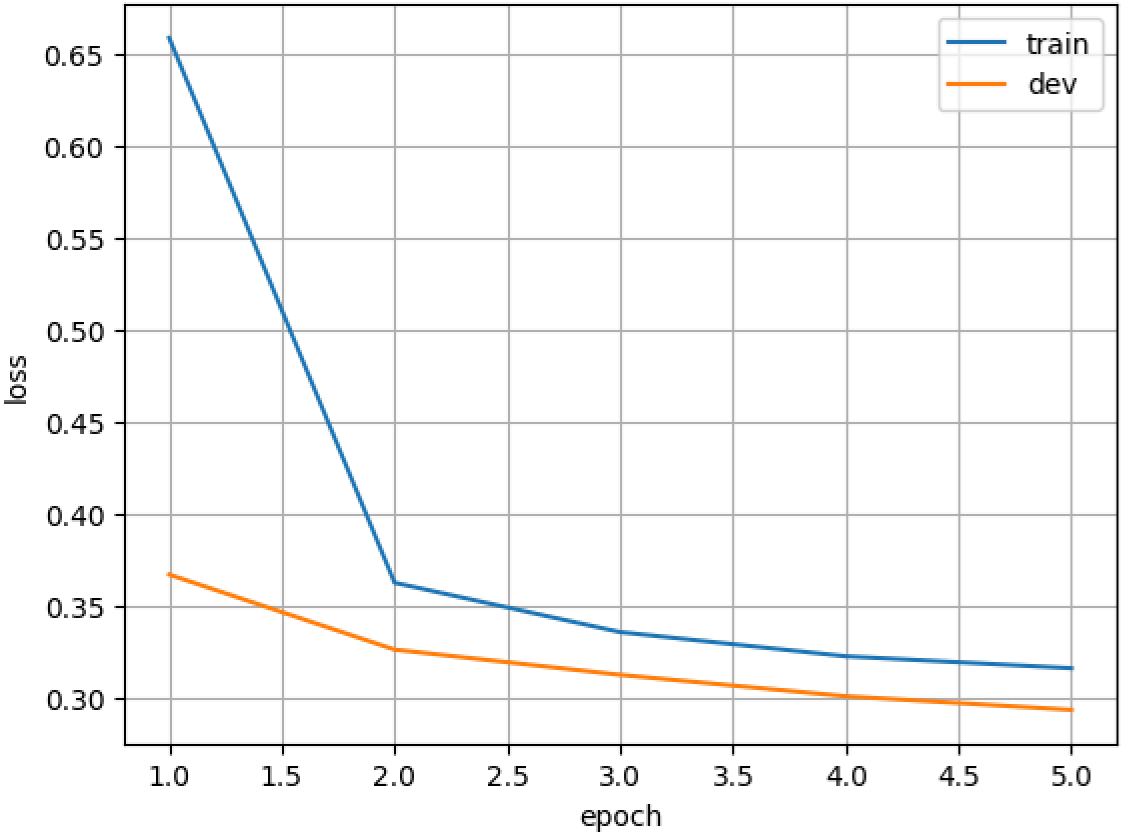
```
epoch 1 (train):   0%|          | 0/192 [00:00<?, ?it/s]
epoch 1 (dev):   0%|          | 0/48 [00:00<?, ?it/s]
epoch 2 (train):   0%|          | 0/192 [00:00<?, ?it/s]
epoch 2 (dev):   0%|          | 0/48 [00:00<?, ?it/s]
epoch 3 (train):   0%|          | 0/192 [00:00<?, ?it/s]
epoch 3 (dev):   0%|          | 0/48 [00:00<?, ?it/s]
epoch 4 (train):   0%|          | 0/192 [00:00<?, ?it/s]
epoch 4 (dev):   0%|          | 0/48 [00:00<?, ?it/s]
epoch 5 (train):   0%|          | 0/192 [00:00<?, ?it/s]
epoch 5 (dev):   0%|          | 0/48 [00:00<?, ?it/s]
```

En esta parte primero se definen los hiperparámetros como la tasa de aprendizaje (lr), tamaño de lote (batch_size), cantidad de épocas (n_epochs), dimensión de la capa oculta (hidden_dim), número de clases (output_dim), y otros valores para dropout y embeddings preentrenados. Luego, se inicializa el modelo con estos valores, junto con una función de pérdida (CrossEntropyLoss) y el optimizador Adam. Durante el entrenamiento, el modelo calcula predicciones para cada batch, mide la pérdida y actualiza los parámetros. Al final de cada época, el modelo se evalúa en el conjunto de validación, calculando la precisión y pérdida promedio en este conjunto sin modificar los parámetros del modelo. Estos valores se registran para monitorear el progreso del modelo en entrenamiento y validación.

Let's plot the loss and accuracy on dev:

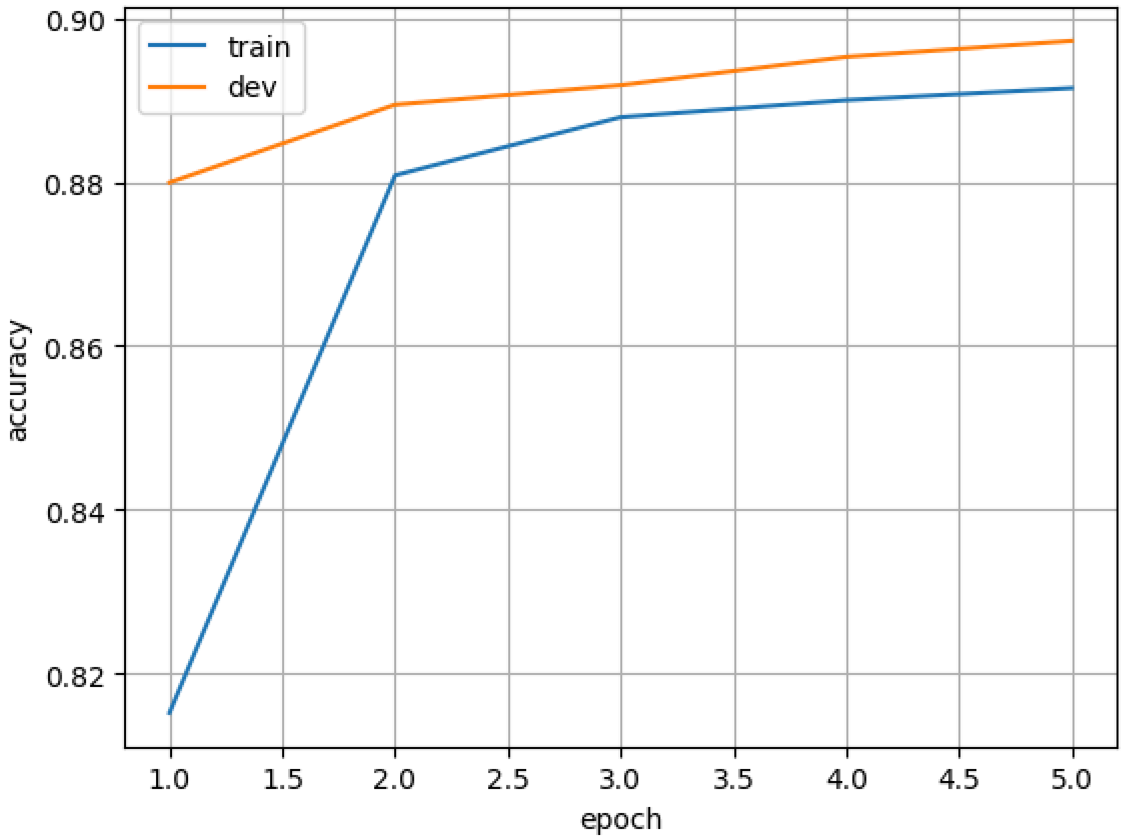
In [26]:

```
import matplotlib.pyplot as plt

%matplotlib inline



x = np.arange(n_epochs) + 1



plt.plot(x, train_loss)

plt.plot(x, dev_loss)

plt.legend(['train', 'dev'])

plt.xlabel('epoch')
plt.ylabel('loss')

plt.grid(True)
```



In [27]:

```
plt.plot(x, train_acc)

plt.plot(x, dev_acc)

plt.legend(['train', 'dev'])

plt.xlabel('epoch')

plt.ylabel('accuracy')

plt.grid(True)
```



Se observan las gráficas del desempeño del modelo. Y acontinuación se repite el procedimiento anterior para el dataset de prueba.

Next, we evaluate on the testing partition:

In [29]:

```
# repeat all preprocessing done above, this time on the test set

test_df = pd.read_csv('/kaggle/input/test-csv/test.csv', header=None)

test_df.columns = ['class index', 'title', 'description']

test_df['text'] = test_df['title'].str.lower() + " " + test_df['description'].str.lowe

test_df['text'] = test_df['text'].str.replace('\\', ' ', regex=False)

test_df['tokens'] = test_df['text'].progress_map(word_tokenize)

max_tokens = dev_df['tokens'].map(len).max()

test_df['token ids'] = test_df['tokens'].progress_map(token_ids)
```

```
  0%|          | 0/7601 [00:00<?, ?it/s]
  0%|          | 0/7601 [00:00<?, ?it/s]
```

In [31]:

```
from sklearn.metrics import classification_report

test_df['class index'] = pd.to_numeric(test_df['class index'], errors='coerce')
test_df = test_df.dropna(subset=['class index']).reset_index(drop=True)

# set model to evaluation mode
```

```
model.eval()


dataset = MyDataset(test_df['token ids'], test_df['class index'] - 1)

data_loader = DataLoader(dataset, batch_size=batch_size)

y_pred = []



# don't store gradients

with torch.no_grad():

    for X, _ in tqdm(data_loader):

        X = X.to(device)

        # predict one class per example

        y = torch.argmax(model(X), dim=1)

        # convert tensor to numpy array (sending it back to the cpu if needed)

        y_pred.append(y.cpu().numpy())

        # print results

    print(classification_report(dataset.y, np.concatenate(y_pred), target_names=labels
```

```
  0%|          | 0/16 [00:00<?, ?it/s]
              precision    recall  f1-score   support

       World       0.92      0.88      0.90      1900
      Sports       0.95      0.97      0.96      1900
    Business       0.85      0.85      0.85      1900
    Sci/Tech       0.86      0.88      0.87      1900

    accuracy                           0.90      7600
   macro avg       0.90      0.90      0.90      7600
weighted avg       0.90      0.90      0.90      7600
```