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Part 1 Topic Classification

In [1]:
```
import pandas as pd
import numpy as np
import nltk
import re
import itertools
import matplotlib.pyplot as plt
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.stem import PorterStemmer,WordNetLemmatizer
from sklearn.feature_extraction.text import ENGLISH_STOP_WORDS,CountVectorizer
from sklearn.model_selection import cross_val_predict,cross_val_score,cross_vali
from sklearn.naive_bayes import MultinomialNB,BernoulliNB
from sklearn.metrics import accuracy_score, classification_report
from sklearn.svm import LinearSVC
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity, euclidean_distances
```

In [2]:
```
# Check the Data
df = pd.read_csv('dataset.tsv', sep='\t')
print(f"Shape: {df.shape}")
print(f"Columns: {df.columns.tolist()}")
df
```

```
Shape: (1500, 6)
Columns: ['artist_name', 'track_name', 'release_date', 'genre', 'lyrics', 'topi
c']
```

Out[2]:

	artist_name	track_name	release_date	genre	lyrics	topic
0	loving	the not real lake	2016	rock	awake know go see time clear world mirror worl...	dark
1	incubus	into the summer	2019	rock	shouldn summer pretty build spill ready overfl...	lifestyle
2	reignwolf	hardcore	2016	blues	lose deep catch breath think say try break wal...	sadness
3	tedeschi trucks band	anyhow	2016	blues	run bitter taste take rest feel anchor soul pl...	sadness
4	lukas nelson and promise of the real	if i started over	2017	blues	think think different set apart sober mind sym...	dark
...	...	...	...	...	...	...
1495	ra ra riot	absolutely	2016	rock	year absolutely absolutely absolutely crush ab...	emotion
1496	mat kearney	face to face	2018	rock	breakthrough hours hear truth moments trade fa...	dark
1497	owane	born in space	2018	jazz	look look right catch blue eye own state breat...	dark
1498	nappy roots	blowin' trees	2019	hip hop	nappy root gotta alright flyin dear leave lone...	personal
1499	skillet	stars	2016	rock	speak word life begin tell oceans start motion...	sadness

1500 rows × 6 columns

In [3]:

```
# Label Check: Topic
topic_count = df['topic'].value_counts()
topic_count
```

Out[3]:

```
topic
dark         490
sadness      376
personal     347
lifestyle    205
emotion       82
Name: count, dtype: int64
```

Part 1.1

(i) The regex in the tutorial is too simple and directly removes all non-letter, number, and space characters. But unlike the news, music data contains a large number of special expressions and symbols, such as words with apostrophes or hyphens (rock'n'roll and hip-hop), as well as frequent abbreviations (don't, can't, I'm, etc.) and emotional punctuation (!, ?) . These contents may have an important impact on semantic understanding and model performance. Therefore, I plan to use a more flexible approach for regex processing, try to keep meaningful special characters, and replace some symbols with Spaces instead of removing them directly, and further optimize the preprocessing based on the performance of the model.

(ii) The evaluation methods in the tutorial are based on only a single train-test split, which makes the evaluation results highly dependent on a single random split and lacks stability and representation. At the same time, by the preliminary observation of the dataset, it can be seen that the class distribution is obviously unbalanced, and a single division may lead to some classes being underestimated or omitted in the validation set. I will use Stratified K-Fold Cross-Validation in future experiments to improve the reliability of model evaluation and ensure that each class is adequately and evenly covered.

Part 1.2

In this part, I use Multinomial Naive Bayes (MNB) model to compare the performance of several text preprocessing strategies on the task of music topic classification.

Specifically, strategies include whether to remove special characters (remove_special_chars), regular expression patterns (regex), removal strategy (strategy), lowercase, stop word removal (stp), stop word sources (stp_s), and stemming or stemming.

I evaluated the classification performance of the MNB model using five-fold cross validation by looping over all possible combinations of text preprocessing strategies, as shown in the following code and results:

In [4]:
```
# Concatenate all features
df['Content'] = (
    df['artist_name'].astype(str) + ' ' +
    df['track_name'].astype(str) + ' ' +
    df['release_date'].astype(str) + ' ' +
    df['genre'].astype(str) + ' ' +
    df['lyrics'].astype(str)
)
df = df[['Content', 'topic']]

# Drop duplicates and missing values
df = df.drop_duplicates()
df = df.dropna()

df
```

Out[4]:

	Content	topic
0	loving the not real lake 2016 rock awake know ...	dark
1	incubus into the summer 2019 rock shouldn summ...	lifestyle
2	reignwolf hardcore 2016 blues lose deep catch ...	sadness
3	tedeschi trucks band anyhow 2016 blues run bit...	sadness
4	lukas nelson and promise of the real if i star...	dark
...	...	...
1495	ra ra riot absolutely 2016 rock year absolutel...	emotion
1496	mat kearney face to face 2018 rock breakthroug...	dark
1497	owane born in space 2018 jazz look look right ...	dark
1498	nappy roots blowin' trees 2019 hip hop nappy r...	personal
1499	skillet stars 2016 rock speak word life begin ...	sadness

1480 rows × 2 columns

In [5]:

```
# Download NLTK
nltk.download('stopwords')
nltk.download('punkt')
nltk.download('punkt_tab')
nltk.download('wordnet')
```

```
[nltk_data] Downloading package stopwords to
[nltk_data]     C:\Users\Aufb\AppData\Roaming\nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package punkt to
[nltk_data]     C:\Users\Aufb\AppData\Roaming\nltk_data...
[nltk_data]   Package punkt is already up-to-date!
[nltk_data] Downloading package punkt_tab to
[nltk_data]     C:\Users\Aufb\AppData\Roaming\nltk_data...
[nltk_data]   Package punkt_tab is already up-to-date!
[nltk_data] Downloading package wordnet to
[nltk_data]     C:\Users\Aufb\AppData\Roaming\nltk_data...
[nltk_data]   Package wordnet is already up-to-date!
```

Out[5]: True

In [6]:

```
def preprocess_text(text,
                    remove_special_chars=True,
                    regex=r'[^\w\s]',
                    strategy='remove',     # 'remove' or 'replace_space'
                    lowercase=True,
                    stp=True,
                    stp_s='nltk', # 'nltk' or 'sklearn'
                    stemming='none'       # 'porter', 'lemma', or 'none'
):
    if lowercase:
        text = text.lower()

    if remove_special_chars: # Handle special characters
        if strategy == 'replace_space':# Replace with Spaces
```

```python
            text = re.sub(regex, ' ', text)
        else:  # remove
            text = re.sub(regex, '', text)
    text = re.sub(r'\s+', ' ', text).strip() # Clear out redundant Spaces

    tokens = word_tokenize(text)

    if stp: # Get stop words
        if stp_s == 'nltk':
            stp_words = set(stopwords.words('english'))
        else:  # sklearn
            stp_words = ENGLISH_STOP_WORDS

    if stemming == 'porter': # Initialize the stem extractor
        ps = PorterStemmer()
    elif stemming == 'lemma':
        lemmatizer = WordNetLemmatizer()
    if stp:
        tokens = [word for word in tokens if word not in stp_words]

    if stemming== 'porter': # Stem extraction
        tokens = [ps.stem(token) for token in tokens]
    elif stemming== 'lemma':
        tokens = [lemmatizer.lemmatize(token) for token in tokens]
    return ' '.join(tokens)
```

In [7]:

```python
remove_special_chars=[True,False]
regex = [r"[^\w\s]",r"[^\w\s']",r"[^\w\s'-]",r"[^\w\s'!?]",r"[^\w\s'!?-]",r"[^\w
strategy=['remove','replace_space']
lowercase=[True,False]
stp=[True,False]
stp_s=['nltk' , 'sklearn']
stemming=['porter', 'lemma', 'none']

param_grid = list(itertools.product(remove_special_chars, regex, strategy, lower

best_mean = 0
best_std = None
best_col = None
best_params = None

# Test all strategies
for idx, params in enumerate(param_grid):
    rsc, rx, stg, low, stpw, stpw_s, stm = params
    col_name = f'Content_pro'

    df[col_name] = df['Content'].apply(lambda x:
        preprocess_text(
            x,
            remove_special_chars=rsc,
            regex=rx,
            strategy=stg,
            lowercase=low,
            stp=stpw,
            stp_s=stpw_s,
            stemming=stm
        )
    )

    vectorizer = CountVectorizer()
```

```python
    X = vectorizer.fit_transform(df[col_name])
    y = df['topic']
    mnb = MultinomialNB()
    scores = cross_val_score(mnb, X, y, cv=5, scoring='accuracy')
    mean_acc = scores.mean()
    std_acc = scores.std()

    print(f"{idx} Acc:{mean_acc:.4f}, Params: {str(params)}")

    if mean_acc > best_mean:
        best_mean = mean_acc
        best_std = std_acc
        best_col = col_name
        best_params = params

print("\nBest combination: {} | Mean Accuracy: {:.4f} | Std: {:.4f}".format(
    best_col, best_mean, best_std
))
print("Best params:", best_params)
```

```
0 Acc:0.7858, Params: (True, '[^\\w\\s]', 'remove', True, True, 'nltk', 'porter')
1 Acc:0.7905, Params: (True, '[^\\w\\s]', 'remove', True, True, 'nltk', 'lemma')
2 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', True, True, 'nltk', 'none')
3 Acc:0.7811, Params: (True, '[^\\w\\s]', 'remove', True, True, 'sklearn', 'porte
r')
4 Acc:0.7784, Params: (True, '[^\\w\\s]', 'remove', True, True, 'sklearn', 'lemm
a')
5 Acc:0.7811, Params: (True, '[^\\w\\s]', 'remove', True, True, 'sklearn', 'non
e')
6 Acc:0.7845, Params: (True, '[^\\w\\s]', 'remove', True, False, 'nltk', 'porte
r')
7 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', True, False, 'nltk', 'lemma')
8 Acc:0.7892, Params: (True, '[^\\w\\s]', 'remove', True, False, 'nltk', 'none')
9 Acc:0.7845, Params: (True, '[^\\w\\s]', 'remove', True, False, 'sklearn', 'port
er')
10 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', True, False, 'sklearn', 'lem
ma')
11 Acc:0.7892, Params: (True, '[^\\w\\s]', 'remove', True, False, 'sklearn', 'non
e')
12 Acc:0.7858, Params: (True, '[^\\w\\s]', 'remove', False, True, 'nltk', 'porte
r')
13 Acc:0.7905, Params: (True, '[^\\w\\s]', 'remove', False, True, 'nltk', 'lemm
a')
14 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', False, True, 'nltk', 'none')
15 Acc:0.7811, Params: (True, '[^\\w\\s]', 'remove', False, True, 'sklearn', 'por
ter')
16 Acc:0.7784, Params: (True, '[^\\w\\s]', 'remove', False, True, 'sklearn', 'lem
ma')
17 Acc:0.7811, Params: (True, '[^\\w\\s]', 'remove', False, True, 'sklearn', 'non
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18 Acc:0.7845, Params: (True, '[^\\w\\s]', 'remove', False, False, 'nltk', 'porte
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19 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', False, False, 'nltk', 'lemm
a')
20 Acc:0.7892, Params: (True, '[^\\w\\s]', 'remove', False, False, 'nltk', 'non
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21 Acc:0.7845, Params: (True, '[^\\w\\s]', 'remove', False, False, 'sklearn', 'po
rter')
22 Acc:0.7912, Params: (True, '[^\\w\\s]', 'remove', False, False, 'sklearn', 'le
mma')
23 Acc:0.7892, Params: (True, '[^\\w\\s]', 'remove', False, False, 'sklearn', 'no
ne')
24 Acc:0.7865, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'nltk',
'porter')
25 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'nltk',
'lemma')
26 Acc:0.7899, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'nltk',
'none')
27 Acc:0.7797, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'sklear
n', 'porter')
28 Acc:0.7804, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'sklear
n', 'lemma')
29 Acc:0.7804, Params: (True, '[^\\w\\s]', 'replace_space', True, True, 'sklear
n', 'none')
30 Acc:0.7824, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'nltk',
'porter')
31 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'nltk',
'lemma')
32 Acc:0.7878, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'nltk',
'none')
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33 Acc:0.7824, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'sklear
n', 'porter')
34 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'sklear
n', 'lemma')
35 Acc:0.7878, Params: (True, '[^\\w\\s]', 'replace_space', True, False, 'sklear
n', 'none')
36 Acc:0.7865, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'nltk',
'porter')
37 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'nltk',
'lemma')
38 Acc:0.7899, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'nltk',
'none')
39 Acc:0.7797, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'sklear
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40 Acc:0.7804, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'sklear
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41 Acc:0.7804, Params: (True, '[^\\w\\s]', 'replace_space', False, True, 'sklear
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42 Acc:0.7824, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'nltk',
'porter')
43 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'nltk',
'lemma')
44 Acc:0.7878, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'nltk',
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45 Acc:0.7824, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'sklear
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46 Acc:0.7885, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'sklear
n', 'lemma')
47 Acc:0.7878, Params: (True, '[^\\w\\s]', 'replace_space', False, False, 'sklear
n', 'none')
48 Acc:0.7858, Params: (True, "[^\\w\\s']", 'remove', True, True, 'nltk', 'porte
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49 Acc:0.7905, Params: (True, "[^\\w\\s']", 'remove', True, True, 'nltk', 'lemm
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50 Acc:0.7899, Params: (True, "[^\\w\\s']", 'remove', True, True, 'nltk', 'none')
51 Acc:0.7811, Params: (True, "[^\\w\\s']", 'remove', True, True, 'sklearn', 'por
ter')
52 Acc:0.7791, Params: (True, "[^\\w\\s']", 'remove', True, True, 'sklearn', 'lem
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53 Acc:0.7797, Params: (True, "[^\\w\\s']", 'remove', True, True, 'sklearn', 'non
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54 Acc:0.7845, Params: (True, "[^\\w\\s']", 'remove', True, False, 'nltk', 'porte
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55 Acc:0.7912, Params: (True, "[^\\w\\s']", 'remove', True, False, 'nltk', 'lemm
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56 Acc:0.7892, Params: (True, "[^\\w\\s']", 'remove', True, False, 'nltk', 'non
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57 Acc:0.7845, Params: (True, "[^\\w\\s']", 'remove', True, False, 'sklearn', 'po
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58 Acc:0.7912, Params: (True, "[^\\w\\s']", 'remove', True, False, 'sklearn', 'le
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59 Acc:0.7892, Params: (True, "[^\\w\\s']", 'remove', True, False, 'sklearn', 'no
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60 Acc:0.7858, Params: (True, "[^\\w\\s']", 'remove', False, True, 'nltk', 'porte
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61 Acc:0.7905, Params: (True, "[^\\w\\s']", 'remove', False, True, 'nltk', 'lemm
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62 Acc:0.7899, Params: (True, "[^\\w\\s']", 'remove', False, True, 'nltk', 'non
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63 Acc:0.7811, Params: (True, "[^\\w\\s']", 'remove', False, True, 'sklearn', 'po
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64 Acc:0.7791, Params: (True, "[^\\w\\s']", 'remove', False, True, 'sklearn', 'le
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65 Acc:0.7797, Params: (True, "[^\\w\\s']", 'remove', False, True, 'sklearn', 'no
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66 Acc:0.7845, Params: (True, "[^\\w\\s']", 'remove', False, False, 'nltk', 'port
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67 Acc:0.7912, Params: (True, "[^\\w\\s']", 'remove', False, False, 'nltk', 'lemm
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68 Acc:0.7892, Params: (True, "[^\\w\\s']", 'remove', False, False, 'nltk', 'non
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69 Acc:0.7845, Params: (True, "[^\\w\\s']", 'remove', False, False, 'sklearn', 'p
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70 Acc:0.7912, Params: (True, "[^\\w\\s']", 'remove', False, False, 'sklearn', 'l
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71 Acc:0.7892, Params: (True, "[^\\w\\s']", 'remove', False, False, 'sklearn', 'n
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72 Acc:0.7858, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'nltk',
'porter')
73 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'nltk',
'lemma')
74 Acc:0.7899, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'nltk',
'none')
75 Acc:0.7797, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'sklear
n', 'porter')
76 Acc:0.7797, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'sklear
n', 'lemma')
77 Acc:0.7811, Params: (True, "[^\\w\\s']", 'replace_space', True, True, 'sklear
n', 'none')
78 Acc:0.7838, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'nltk',
'porter')
79 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'nltk',
'lemma')
80 Acc:0.7878, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'nltk',
'none')
81 Acc:0.7838, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'sklear
n', 'porter')
82 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'sklear
n', 'lemma')
83 Acc:0.7878, Params: (True, "[^\\w\\s']", 'replace_space', True, False, 'sklear
n', 'none')
84 Acc:0.7858, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'nltk',
'porter')
85 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'nltk',
'lemma')
86 Acc:0.7899, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'nltk',
'none')
87 Acc:0.7797, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'sklear
n', 'porter')
88 Acc:0.7797, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'sklear
n', 'lemma')
89 Acc:0.7811, Params: (True, "[^\\w\\s']", 'replace_space', False, True, 'sklear
n', 'none')
90 Acc:0.7838, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'nlt
k', 'porter')
91 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'nlt
k', 'lemma')
92 Acc:0.7878, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'nlt
k', 'none')
93 Acc:0.7838, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'sklea
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rn', 'porter')
94 Acc:0.7885, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'sklea
rn', 'lemma')
95 Acc:0.7878, Params: (True, "[^\\w\\s']", 'replace_space', False, False, 'sklea
rn', 'none')
96 Acc:0.7858, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'nltk', 'porte
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97 Acc:0.7899, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'nltk', 'lemm
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98 Acc:0.7899, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'nltk', 'non
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99 Acc:0.7804, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'sklearn', 'po
rter')
100 Acc:0.7797, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'sklearn', 'l
emma')
101 Acc:0.7791, Params: (True, "[^\\w\\s'-]", 'remove', True, True, 'sklearn', 'n
one')
102 Acc:0.7831, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'nltk', 'por
ter')
103 Acc:0.7912, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'nltk', 'lem
ma')
104 Acc:0.7892, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'nltk', 'non
e')
105 Acc:0.7831, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'sklearn',
'porter')
106 Acc:0.7912, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'sklearn',
'lemma')
107 Acc:0.7892, Params: (True, "[^\\w\\s'-]", 'remove', True, False, 'sklearn',
'none')
108 Acc:0.7858, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'nltk', 'por
ter')
109 Acc:0.7899, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'nltk', 'lem
ma')
110 Acc:0.7899, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'nltk', 'non
e')
111 Acc:0.7804, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'sklearn',
'porter')
112 Acc:0.7797, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'sklearn',
'lemma')
113 Acc:0.7791, Params: (True, "[^\\w\\s'-]", 'remove', False, True, 'sklearn',
'none')
114 Acc:0.7831, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'nltk', 'po
rter')
115 Acc:0.7912, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'nltk', 'le
mma')
116 Acc:0.7892, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'nltk', 'no
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117 Acc:0.7831, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'sklearn',
'porter')
118 Acc:0.7912, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'sklearn',
'lemma')
119 Acc:0.7892, Params: (True, "[^\\w\\s'-]", 'remove', False, False, 'sklearn',
'none')
120 Acc:0.7858, Params: (True, "[^\\w\\s'-]", 'replace_space', True, True, 'nlt
k', 'porter')
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494 Acc:0.7899, Params: (False, "[^\\w\\s'!?-]", 'remove', False, True, 'nltk',
'none')
495 Acc:0.7804, Params: (False, "[^\\w\\s'!?-]", 'remove', False, True, 'sklear
n', 'porter')
496 Acc:0.7797, Params: (False, "[^\\w\\s'!?-]", 'remove', False, True, 'sklear
n', 'lemma')
497 Acc:0.7811, Params: (False, "[^\\w\\s'!?-]", 'remove', False, True, 'sklear
n', 'none')
498 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'nltk',
'porter')
499 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'nltk',
'lemma')
500 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'nltk',
'none')
501 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'sklear
n', 'porter')
502 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'sklear
n', 'lemma')
503 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'remove', False, False, 'sklear
n', 'none')
504 Acc:0.7851, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'nl
tk', 'porter')
505 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'nl
tk', 'lemma')
506 Acc:0.7899, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'nl
tk', 'none')
507 Acc:0.7804, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'sk
learn', 'porter')
508 Acc:0.7797, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'sk
learn', 'lemma')
509 Acc:0.7811, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, True, 'sk
learn', 'none')
510 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 'n
ltk', 'porter')
511 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 'n
ltk', 'lemma')
512 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 'n
ltk', 'none')
513 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 's
```

```
klearn', 'porter')
514 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 's
klearn', 'lemma')
515 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'replace_space', True, False, 's
klearn', 'none')
516 Acc:0.7851, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 'n
ltk', 'porter')
517 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 'n
ltk', 'lemma')
518 Acc:0.7899, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 'n
ltk', 'none')
519 Acc:0.7804, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 's
klearn', 'porter')
520 Acc:0.7797, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 's
klearn', 'lemma')
521 Acc:0.7811, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, True, 's
klearn', 'none')
522 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'nltk', 'porter')
523 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'nltk', 'lemma')
524 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'nltk', 'none')
525 Acc:0.7838, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'sklearn', 'porter')
526 Acc:0.7885, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'sklearn', 'lemma')
527 Acc:0.7878, Params: (False, "[^\\w\\s'!?-]", 'replace_space', False, False,
'sklearn', 'none')
528 Acc:0.7851, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'nltk', 'p
orter')
529 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'nltk', 'l
emma')
530 Acc:0.7899, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'nltk', 'n
one')
531 Acc:0.7804, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'sklearn',
'porter')
532 Acc:0.7797, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'sklearn',
'lemma')
533 Acc:0.7811, Params: (False, "[^\\w\\s'!?.]", 'remove', True, True, 'sklearn',
'none')
534 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'nltk',
'porter')
535 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'nltk',
'lemma')
536 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'nltk',
'none')
537 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'sklear
n', 'porter')
538 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'sklear
n', 'lemma')
539 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'remove', True, False, 'sklear
n', 'none')
540 Acc:0.7851, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'nltk',
'porter')
541 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'nltk',
'lemma')
542 Acc:0.7899, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'nltk',
'none')
543 Acc:0.7804, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'sklear
```

```
n', 'porter')
544 Acc:0.7797, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'sklear
n', 'lemma')
545 Acc:0.7811, Params: (False, "[^\\w\\s'!?.]", 'remove', False, True, 'sklear
n', 'none')
546 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'nltk',
'porter')
547 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'nltk',
'lemma')
548 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'nltk',
'none')
549 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'sklear
n', 'porter')
550 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'sklear
n', 'lemma')
551 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'remove', False, False, 'sklear
n', 'none')
552 Acc:0.7851, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'nl
tk', 'porter')
553 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'nl
tk', 'lemma')
554 Acc:0.7899, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'nl
tk', 'none')
555 Acc:0.7804, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'sk
learn', 'porter')
556 Acc:0.7797, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'sk
learn', 'lemma')
557 Acc:0.7811, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, True, 'sk
learn', 'none')
558 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 'n
ltk', 'porter')
559 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 'n
ltk', 'lemma')
560 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 'n
ltk', 'none')
561 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 's
klearn', 'porter')
562 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 's
klearn', 'lemma')
563 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'replace_space', True, False, 's
klearn', 'none')
564 Acc:0.7851, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 'n
ltk', 'porter')
565 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 'n
ltk', 'lemma')
566 Acc:0.7899, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 'n
ltk', 'none')
567 Acc:0.7804, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 's
klearn', 'porter')
568 Acc:0.7797, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 's
klearn', 'lemma')
569 Acc:0.7811, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, True, 's
klearn', 'none')
570 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
'nltk', 'porter')
571 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
'nltk', 'lemma')
572 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
'nltk', 'none')
573 Acc:0.7838, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
```

```
'sklearn', 'porter')
574 Acc:0.7885, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
'sklearn', 'lemma')
575 Acc:0.7878, Params: (False, "[^\\w\\s'!?.]", 'replace_space', False, False,
'sklearn', 'none')

Best combination: Content_pro | Mean Accuracy: 0.7912 | Std: 0.0241
Best params: (True, "[^\\w\\s'-]", 'remove', True, False, 'nltk', 'lemma')
```

After testing all combinations of text preprocessing parameters, the best solution was as follows: remove_special_chars=True (removes special characters); regex retain only letters, numbers, spaces and hyphens, while removing all other characters; strategy='remove' (removes matched special characters directly), lowercase=True (convert all text to lowercase), stp=False (do not remove stopwords), and stemming='lemma' (apply lemma). Under 5-fold cross validation, the average accuracy of this preprocessing scheme is 0.7912.

The setting of regex has a negligible impact on the model performance. This is because there are almost no special characters in the entire file. At the same time, not removing stop words can help distinguish different themes in the context of music, because a large number of high-frequency "stop words" may carry emotional, structural, or thematic cues (e.g., "I", "you", "we", etc.) in the lyrics. Lemmatization further normalizes different word forms, reduces feature sparsity and improves classification performance.

Part 1.3

In [8]:

```python
df['Content_pro'] = df['Content'].apply(lambda x:
    preprocess_text(x, remove_special_chars=True, regex=r"[^\w\s'-]", strategy='
                    lowercase=True, stp=False, stemming='lemma')
)
vectorizer = CountVectorizer()
X = vectorizer.fit_transform(df['Content_pro'])
y = df['topic']

mnb = MultinomialNB()
bnb = BernoulliNB()

k=5
scoring = ['accuracy', 'precision_macro', 'recall_macro', 'f1_macro', 'f1_weight
mnb_results = cross_validate(mnb, X, y, cv=k, scoring=scoring)
bnb_results = cross_validate(bnb, X, y, cv=k, scoring=scoring)

mnb_score = [round(float(mnb_results['test_'+m].mean()), 10) for m in scoring]
bnb_score = [round(float(bnb_results['test_'+m].mean()), 10) for m in scoring]

print(scoring)
print(mnb_score)
print(bnb_score)

y_pred_mnb = cross_val_predict(mnb, X, y, cv=k)
print("MultinomialNB: ")
print(classification_report(y, y_pred_mnb, digits=4))

y_pred_bnb = cross_val_predict(bnb, X, y, cv=k)
```

```
print("BernoulliNB: ")
print(classification_report(y, y_pred_bnb, digits=4))
```

```
['accuracy', 'precision_macro', 'recall_macro', 'f1_macro', 'f1_weighted']
[0.7912162162, 0.749429649, 0.7002959332, 0.713780753, 0.7853218593]
[0.5216216216, 0.3499769901, 0.3743116912, 0.3285881193, 0.4553346177]
MultinomialNB:
              precision    recall  f1-score   support

        dark     0.8125    0.8275    0.8199       487
     emotion     0.5000    0.2911    0.3680        79
   lifestyle     0.8457    0.6782    0.7527       202
    personal     0.8480    0.8182    0.8328       341
     sadness     0.7360    0.8868    0.8044       371

    accuracy                         0.7912      1480
   macro avg     0.7484    0.7004    0.7156      1480
weighted avg     0.7894    0.7912    0.7857      1480

BernoulliNB:
              precision    recall  f1-score   support

        dark     0.6033    0.7495    0.6685       487
     emotion     0.0000    0.0000    0.0000        79
   lifestyle     0.0714    0.0050    0.0093       202
    personal     0.6443    0.2815    0.3918       341
     sadness     0.4385    0.8356    0.5751       371

    accuracy                         0.5216      1480
   macro avg     0.3515    0.3743    0.3289      1480
weighted avg     0.4666    0.5216    0.4557      1480
```

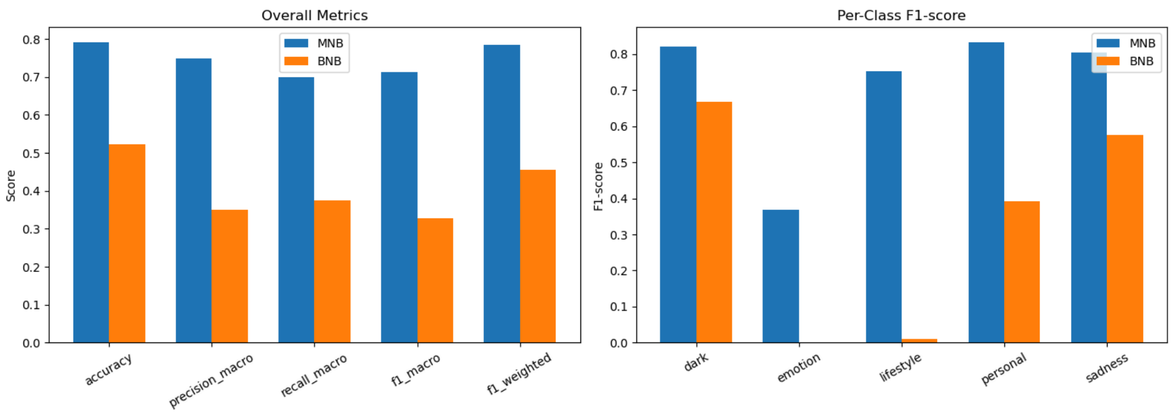
```
C:\Python\anaconda\envs\comp\lib\site-packages\sklearn\metrics\_classification.p
y:1565: UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in
labels with no predicted samples. Use `zero_division` parameter to control this b
ehavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
C:\Python\anaconda\envs\comp\lib\site-packages\sklearn\metrics\_classification.p
y:1565: UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in
labels with no predicted samples. Use `zero_division` parameter to control this b
ehavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

In [9]:

```
mnb_report = classification_report(y, y_pred_mnb, output_dict=True)
bnb_report = classification_report(y, y_pred_bnb, output_dict=True)
print(y)

categories = sorted(list(set(y)))

mnb_f1 = [mnb_report[c]['f1-score'] for c in categories]
bnb_f1 = [bnb_report[c]['f1-score'] for c in categories]

labels = scoring
x = np.arange(len(labels))
width = 0.35

fig, axes = plt.subplots(1, 2, figsize=(14, 5))

axes[0].bar(x - width/2, mnb_score, width, label='MNB')
axes[0].bar(x + width/2, bnb_score, width, label='BNB')
```

```
axes[0].set_ylabel('Score')
axes[0].set_title('Overall Metrics')
axes[0].set_xticks(x)
axes[0].set_xticklabels(labels, rotation=30)
axes[0].legend()

cat_x = np.arange(len(categories))
axes[1].bar(cat_x - width/2, mnb_f1, width, label='MNB')
axes[1].bar(cat_x + width/2, bnb_f1, width, label='BNB')
axes[1].set_ylabel('F1-score')
axes[1].set_title('Per-Class F1-score')
axes[1].set_xticks(cat_x)
axes[1].set_xticklabels(categories, rotation=30)
axes[1].legend()

plt.tight_layout()
plt.show()
```

```
0            dark
1       lifestyle
2         sadness
3         sadness
4            dark
          ...
1495      emotion
1496         dark
1497         dark
1498     personal
1499      sadness
Name: topic, Length: 1480, dtype: object
```



Based on the optimal text preprocessing strategy (from Part 1.2), I compare the performance of MNB and BNB on the music topic classification task using five-fold cross validation. The evaluation metrics cover accuracy, precision, recall, and f1, including the macro average metric as well as the specific performance for each category.

Because of the serious imbalance of this dataset, it is more representative to use the global macro average metric to evaluate the model performance. In particular, F1 macro-average score, which integrates precision and recall, can effectively penalize the model for ignoring any class and prevent the model from focusing only on the large class at the expense of the small class.

The experimental results (see bar chart) show that MNB outperforms BNB by a large margin in all evaluation metrics, especially in the macro average metric. This shows that the BNB model is easy to ignore the minority class samples in the context of extremely unbalanced class distribution and high-dimensional text features. From the evaluation results of each category, all evaluation metrics of BNB on emotion category are 0, indicating that the model fails to identify any emotion sample during the whole cross-validation process, completely ignoring this minority class. In contrast, MNB not only has higher overall accuracy, but also has some discrimination ability for all classes, including those with fewer samples.

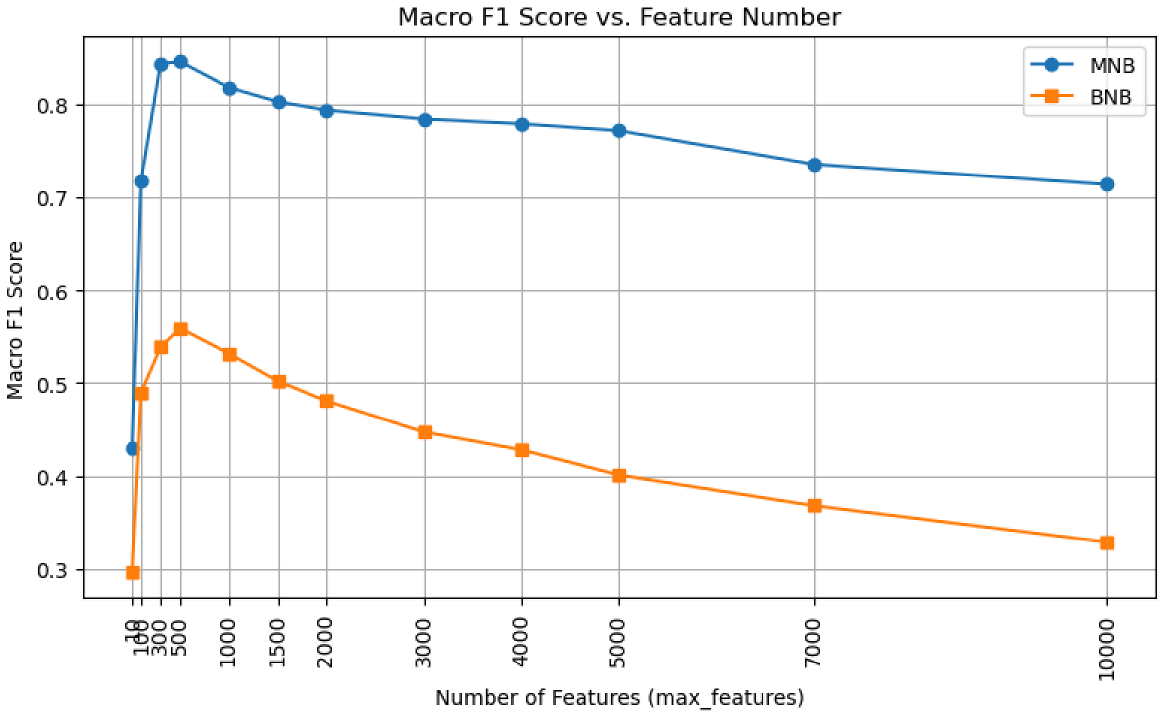
Part 1.4

In [10]:
```
N_list = [10,100, 300, 500, 1000, 1500, 2000, 3000, 4000, 5000, 7000, 10000]
k = 5
mnb_f1_list= []
bnb_f1_list= []

for N in N_list:
    vectorizer = CountVectorizer(max_features=N)
    X = vectorizer.fit_transform(df['Content_pro'])
    y = df['topic']

    mnb = MultinomialNB()
    bnb = BernoulliNB()

    mnb_f1 = cross_val_score(mnb, X, y, cv=k, scoring='f1_macro').mean()
    bnb_f1 = cross_val_score(bnb, X, y, cv=k, scoring='f1_macro').mean()
    mnb_f1_list.append(mnb_f1)
    bnb_f1_list.append(bnb_f1)
    print(f"N={N}, MNB f1: {mnb_f1:.4f}, BNB: {bnb_f1:.4f}")

best_mnb = np.argmax(mnb_f1_list)
best_bnb = np.argmax(bnb_f1_list)
best_N_mnb = N_list[best_mnb]
best_N_bnb = N_list[best_bnb]
print(f"MNB best N = {best_N_mnb}, f1_macro = {mnb_f1_list[best_mnb]:.4f}")
print(f"BNB best N = {best_N_bnb}, f1_macro = {bnb_f1_list[best_bnb]:.4f}")
```

```
N=10, MNB f1: 0.4294, BNB: 0.2961
N=100, MNB f1: 0.7177, BNB: 0.4894
N=300, MNB f1: 0.8433, BNB: 0.5384
N=500, MNB f1: 0.8455, BNB: 0.5588
N=1000, MNB f1: 0.8178, BNB: 0.5316
N=1500, MNB f1: 0.8026, BNB: 0.5020
N=2000, MNB f1: 0.7935, BNB: 0.4805
N=3000, MNB f1: 0.7841, BNB: 0.4472
N=4000, MNB f1: 0.7790, BNB: 0.4279
N=5000, MNB f1: 0.7715, BNB: 0.4008
N=7000, MNB f1: 0.7352, BNB: 0.3679
N=10000, MNB f1: 0.7138, BNB: 0.3286
MNB best N = 500, f1_macro = 0.8455
BNB best N = 500, f1_macro = 0.5588
```

In [11]:
```
plt.figure(figsize=(8,5))
plt.plot(N_list, mnb_f1_list, marker='o', label='MNB')
plt.plot(N_list, bnb_f1_list, marker='s', label='BNB')
plt.xlabel('Number of Features (max_features)')
plt.ylabel('Macro F1 Score')
plt.title('Macro F1 Score vs. Feature Number')
plt.legend()
```

```
plt.grid(True)
plt.xticks(N_list, rotation=90)
plt.tight_layout()
plt.show()
```



In this part, I adopted different max_features parameters (only retaining the top N words with the highest word frequency) to extract features from the text, and compared the performance of the average F1 score of the BNB and MNB models. The experimental results are shown in the line graph. The F1 of BNB and MNB both increase initially as N increases, guiding N to around 500, and then gradually decrease as N increases. It indicates that in the current task, when N is approximately 500, the classification performance of the model is the best.

Part 1.5

In this section, I adopt the Support Vector Machine (SVM) model for music theme classification. SVM is particularly suitable for high-dimensional data scenarios, such as text classification tasks, because it maximizes the intervals between different categories by finding the optimal separated hyperplane, effectively enhancing the generalization ability of the model. Our data is represented by high-dimensional sparse vectors composed of words, which is exactly the type that SVM is good at handling.

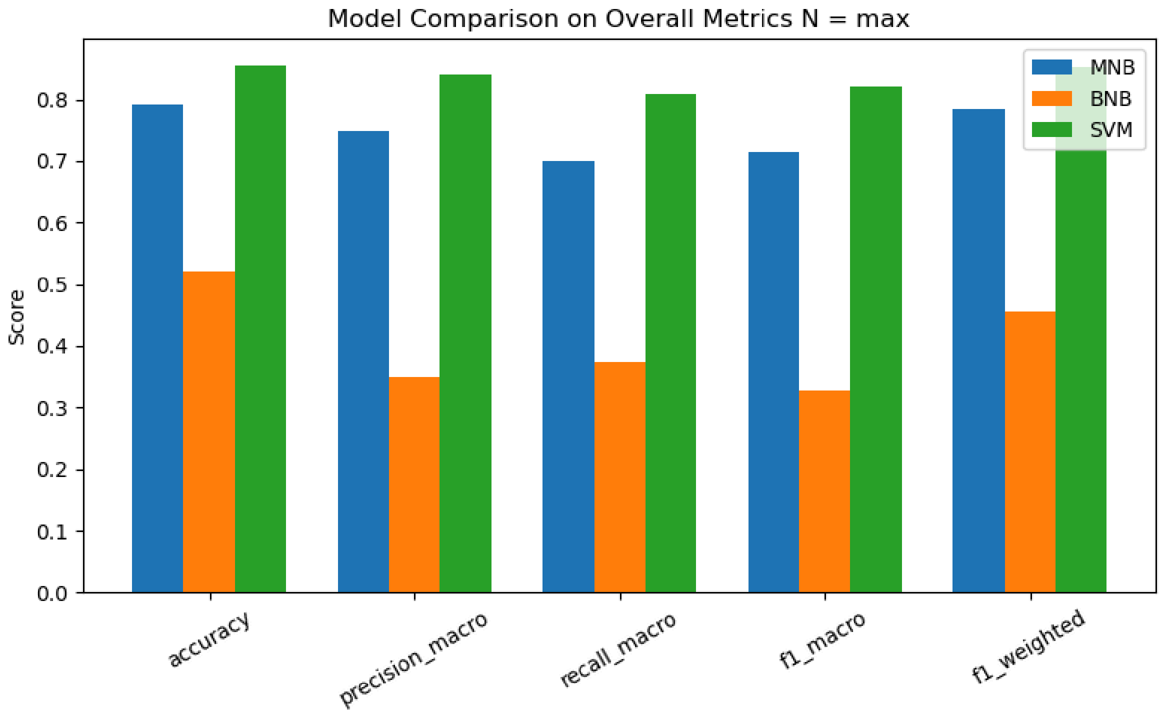
In addition, Saigal et al. analyzed the performance of various SVM variants in Multi-category text classification in the paper "Multi-category news classification using Support Vector Machine based classifiers". The results show that the effect of SVM on the 20 Newsgroups dataset is particularly prominent. 20 Newsgroups is a classic high-dimensional sparse text classification task and has a high similarity with this project. Therefore, SVM is expected to achieve good performance in this task and is expected to achieve higher overall classification performance than BNB in this task. However, since

MNB is good at multiple distributions and has strong performance in classification tasks, the improvement range of SVM may be limited

In [12]:
```
vectorizer = CountVectorizer(max_features=500)
X = vectorizer.fit_transform(df['Content_pro'])
y = df['topic']

svm = LinearSVC(max_iter=3000)

k = 5
scoring = ['accuracy', 'precision_macro', 'recall_macro', 'f1_macro', 'f1_weight
svm_results_N500 = cross_validate(svm, X, y, cv=k, scoring=scoring)

for s in scoring:
    print(f"SVM with N = 500 {s}: {svm_results_N500['test_'+s].mean():.4f}")

vectorizer = CountVectorizer()
X = vectorizer.fit_transform(df['Content_pro'])

svm = LinearSVC(max_iter=3000)

svm_results = cross_validate(svm, X, y, cv=k, scoring=scoring)

for s in scoring:
    print(f"SVM with N = max {s}: {svm_results['test_'+s].mean():.4f}")
```

```
SVM with N = 500 accuracy: 0.8365
SVM with N = 500 precision_macro: 0.8099
SVM with N = 500 recall_macro: 0.7976
SVM with N = 500 f1_macro: 0.8020
SVM with N = 500 f1_weighted: 0.8354
SVM with N = max accuracy: 0.8547
SVM with N = max precision_macro: 0.8398
SVM with N = max recall_macro: 0.8087
SVM with N = max f1_macro: 0.8208
SVM with N = max f1_weighted: 0.8531
```

In [13]:
```
svm_score = [svm_results['test_' + m].mean() for m in scoring]

labels = scoring
x = np.arange(len(labels))
width = 0.25

fig, ax = plt.subplots(figsize=(8, 5))
rects1 = ax.bar(x - width, mnb_score, width, label='MNB')
rects2 = ax.bar(x, bnb_score, width, label='BNB')
rects3 = ax.bar(x + width, svm_score, width, label='SVM')

ax.set_ylabel('Score')
ax.set_title('Model Comparison on Overall Metrics N = max')
ax.set_xticks(x)
ax.set_xticklabels(labels, rotation=30)
ax.legend()

plt.tight_layout()
plt.show()
```



We set two situations for the SVM model: one set the max_features parameter to 500, and the other set no limit on the number of features (using all features). The experimental results of SVM are shown above and compared with BNB and MNB through bar charts when max_features has no limitation. The experimental results show that, unlike the Naive Bayes model, the performance of SVM when max_features=500 is actually lower than that in the case where is not limited. Further observation shows that when N is not limited, the various indicators of SVM are significantly better than those of BNB, and there is also a slight improvement compared with MNB, which is consistent with my initial assumption. However, when N=500, the performance of SVM is slightly lower than that of MNB. Based on the above results and considering that N=500 has been determined as the optimal number of features in previous experiments, I chose MNB as the optimal model and configuration for this task

Part 2

Part 2.1

In [14]:
```
# model from Part 1
N=500
vectorizer = CountVectorizer(max_features=N)
X = vectorizer.fit_transform(df['Content_pro'])
y = df['topic']

mnb = MultinomialNB()
mnb.fit(X, y)

predicted_topics = mnb.predict(X)
df['predicted_topic'] = predicted_topics
df
```

Out[14]:

	Content	topic	Content_pro	predicted_topic
0	loving the not real lake 2016 rock awake know ...	dark	loving the not real lake 2016 rock awake know ...	dark
1	incubus into the summer 2019 rock shouldn summ...	lifestyle	incubus into the summer 2019 rock shouldn summ...	lifestyle
2	reignwolf hardcore 2016 blues lose deep catch ...	sadness	reignwolf hardcore 2016 blue lose deep catch b...	sadness
3	tedeschi trucks band anyhow 2016 blues run bit...	sadness	tedeschi truck band anyhow 2016 blue run bitte...	sadness
4	lukas nelson and promise of the real if i star...	dark	lukas nelson and promise of the real if i star...	dark
...	...	...	...	...
1495	ra ra riot absolutely 2016 rock year absolutel...	emotion	ra ra riot absolutely 2016 rock year absolutel...	emotion
1496	mat kearney face to face 2018 rock breakthroug...	dark	mat kearney face to face 2018 rock breakthroug...	dark
1497	owane born in space 2018 jazz look look right ...	dark	owane born in space 2018 jazz look look right ...	dark
1498	nappy roots blowin' trees 2019 hip hop nappy r...	personal	nappy root blowin tree 2019 hip hop nappy root...	personal
1499	skillet stars 2016 rock speak word life begin ...	sadness	skillet star 2016 rock speak word life begin t...	sadness

1480 rows × 4 columns

In [15]:

```
# Create tf-idf matrixs
train_data = df.iloc[:750]
topic_c = df['predicted_topic'].unique()
matrices=[]
vectorizers={}
for t in topic_c:
    topic_doc=train_data[train_data['predicted_topic'] == t]['Content']
    vectorizer = TfidfVectorizer()
    vectorizer.fit(topic_doc)
    X=vectorizer.transform(topic_doc)
    vectorizers[t] = vectorizer
    matrices.append(X)
print(topic_c[0],matrices[0].shape,topic_c[1],matrices[1].shape,topic_c[2],matri
```

```
dark (244, 4101) lifestyle (93, 1527) sadness (188, 2280) emotion (42, 876) perso
nal (183, 2919)
```

In [16]:

```
user_keywords = []

for user in [1, 2]:
    with open(f'user{user}.tsv', 'r', encoding='utf-8') as f:
        lines = f.readlines()
        theme_keywords = []
        for l in lines:
```

```
            keywords = [i.strip().lower() for i in l.strip().split('\t') if i.st
            theme_keywords.append(keywords)
        user_keywords.append(theme_keywords[1:])

print("User 1:",user_keywords[0], "\nUser 2:", user_keywords[1])
```

```
User 1: [['dark', 'fire, enemy, pain, storm, fight'], ['sadness', 'cry, alone, he
artbroken, tears, regret'], ['personal', 'dream, truth, life, growth, identity'],
['lifestyle', 'party, city, night, light, rhythm'], ['emotion', 'love, memory, hu
g, kiss, feel']]
User 2: [['sadness', 'lost, sorrow, goodbye, tears, silence'], ['emotion', 'roman
ce, touch, feeling, kiss, memory']]
```

In [17]:
```
user_1_like=[]
user_2_like=[]

for word in user_keywords[0]:
    topic=word[0]
    key=[w.strip() for w in word[1].split(',')]
    df_match_topic=train_data[(train_data['predicted_topic'] == topic) & train_d
    user_1_like.append(df_match_topic)

for word in user_keywords[1]:
    topic=word[0]
    key=[w.strip() for w in word[1].split(',')]
    df_match_topic=train_data[(train_data['predicted_topic'] == topic) & train_d
    user_2_like.append(df_match_topic)
user_2_like[1]
```

Out[17]:
```
5      tia ray just my luck 2018 jazz yeah happen rea...
34     cody johnson kiss goodbye 2016 country slide i...
56     tori kelly i was made for loving you 2016 pop ...
248    the struts kiss this 2016 rock say stay home a...
327    t-rock 4:20/reincarnated 2016 hip hop feel fee...
364    311 good feeling 2019 reggae look look time su...
412    esperanza spalding touch in mine (fingers) 201...
423    jd mcpherson on the lips 2017 blues dream like...
448    sufjan stevens visions of gideon 2017 rock lov...
484    gregory porter holding on 2016 jazz weight sho...
541    kbong good lovin 2017 reggae good good good lo...
579    shag rock lip addiction 2017 reggae tonight ru...
633    twenty one pilots cancer 2016 rock turn away d...
728    kelly clarkson love so soft 2017 pop kiss door...
741    weldon irvine morning sunrise 2016 jazz mornin...
Name: Content, dtype: object
```

In [18]:
```
user_1_vector=[]
print("User 1 Profiles =====================================")
for i in range(len(user_1_like)):
    vectorizer = vectorizers[user_keywords[0][i][0]]
    X = vectorizer.transform([' '.join(user_1_like[i])])
    user_1_vector.append(X)
    feature_names = np.array(vectorizer.get_feature_names_out())
    tfidf_weights = X.toarray()[0]
    top_indices = tfidf_weights.argsort()[::-1][:20]
    top_words = feature_names[top_indices]
    print("============",user_keywords[0][i][0],"============")
    print(top_words)
```

```
User 1 Profiles ======================================
============= dark =============
['fight' 'like' 'know' 'black' 'grind' 'blood' 'stand' 'come' 'yeah'
 'tell' 'gonna' 'kill' 'hand' 'cause' 'lanky' 'dilly' 'head' 'follow'
 'good' 'time']
============= sadness =============
['cry' 'club' 'steal' 'tear' 'wish' 'lay' 'mean' 'know' 'baby' 'music'
 'write' 'smile' 'say' 'true' 'think' 'face' 'hand' 'regret' 'eye'
 'greater']
============= personal =============
['life' 'live' 'change' 'world' 'know' 'yeah' 'dream' 'wanna' 'like'
 'thank' 'teach' 'lord' 'come' 'time' 'beat' 'think' 'learn' 'need' 'go'
 'right']
============= lifestyle =============
['tonight' 'night' 'come' 'home' 'closer' 'time' 'strangers' 'song' 'sing'
 'long' 'wait' 'wanna' 'spoil' 'tire' 'right' 'struggle' 'yeah' 'play'
 'mind' 'like']
============= emotion =============
['good' 'touch' 'feel' 'hold' 'know' 'morning' 'video' 'visions' 'loove'
 'kiss' 'vibe' 'feelin' 'want' 'go' 'miss' 'luck' 'sunrise' 'love' 'lovin'
 'gimme']
```

In [19]:

```
print("User 2 Profiles ======================================")
user_2_vector=[]
for i in range(len(user_2_like)):
    vectorizer = vectorizers[user_keywords[1][i][0]]
    X = vectorizer.transform([' '.join(user_2_like[i])])
    user_2_vector.append(X)
    feature_names = np.array(vectorizer.get_feature_names_out())
    tfidf_weights = X.toarray()[0]
    top_indices = tfidf_weights.argsort()[::-1][:20]
    top_words = feature_names[top_indices]
    print("=============",user_keywords[1][i][0],"=============")
    print(top_words)
```

```
User 2 Profiles ======================================
============= sadness =============
['inside' 'break' 'heart' 'step' 'away' 'goodbye' 'violence' 'rainwater'
 'fade' 'blame' 'like' 'hard' 'leave' 'scar' 'open' 'fall' 'magnify' 'go'
 'smile' 'time']
============= emotion =============
['touch' 'good' 'video' 'visions' 'loove' 'kiss' 'hold' 'morning' 'feelin'
 'luck' 'sunrise' 'lovin' 'gimme' 'lips' 'look' 'know' 'time' 'feel'
 'cause' 'addiction']
```

The profiles of user1 and user2 are shown above. The high-weight words in the user profiles are basically consistent with the originally set interest keywords. The portrait directly contains some user interest words. Furthermore, words such as 'fight', 'black', and 'blood' under the 'dark' theme, and 'feel' and 'baby' under the 'emotion' theme are also highly relevant to the corresponding themes. A small number of words such as "like", "know", "time", "yeah", and "na" are common lyrics conjunctions or colloquial expressions. Overall, the user portraits screened out by the recommendation system through interest keywords can better reflect the interest directions of users under different topics, demonstrating the rationality of the recommendation algorithm in simulating user interests.

In [20]:
```
user3_keywords = [
    ['personal', 'hope, future, dream, learn, freedom'],
    ['lifestyle', 'travel, road, summer, sea, friend']
]

user_3_like=[]

for word in user3_keywords:
    topic=word[0]
    key=[w.strip() for w in word[1].split(',')]
    df_match_topic=train_data[(train_data['predicted_topic'] == topic) & train_d
    user_3_like.append(df_match_topic)

print("User 3 Profiles =====================================")
user_3_vector=[]
for i in range(len(user_3_like)):
    vectorizer = vectorizers[user3_keywords[i][0]]
    X = vectorizer.transform([' '.join(user_3_like[i])])
    user_3_vector.append(X)
    feature_names = np.array(vectorizer.get_feature_names_out())
    tfidf_weights = X.toarray()[0]
    top_indices = tfidf_weights.argsort()[::-1][:20]
    top_words = feature_names[top_indices]
    print("=============",user3_keywords[i][0],"=============")
    print(top_words)
```

```
User 3 Profiles =====================================
============= personal =============
['thank' 'life' 'change' 'dream' 'world' 'yeah' 'learn' 'live' 'know'
 'come' 'wanna' 'automaton' 'like' 'everybody' 'time' 'cause' 'right'
 'gotta' 'think' 'feel']
============= lifestyle =============
['home' 'song' 'tonight' 'tire' 'come' 'sing' 'telephone' 'summer' 'ring'
 'lalala' 'revelator' 'songs' 'write' 'hallelujah' 'long' 'wait' 'yeah'
 'wanna' 'tell' 'oohoohooh']
```

The above are the keywords defined by User3, and the top 20 high-weight TF-IDF words under each topic are displayed. Similar to User1 and User2, most of the high-weight words in User3's profile can accurately reflect the interest directions it has set. Except for a few common lyric conjunctions or colloquial expressions, other words are highly relevant to the corresponding themes, indicating that the construction of user profiles still has good rationality.

Part 2.2

In [21]:
```
def jaccard_similarity(a, b):
    if hasattr(a, 'toarray'):
        a = a.toarray()
    if hasattr(b, 'toarray'):
        b = b.toarray()
    a = np.asarray(a).ravel()
    b = np.asarray(b).ravel()
    intersection = np.logical_and(a > 0, b > 0).sum()
    union = np.logical_or(a > 0, b > 0).sum()
    return intersection / union if union > 0 else 0
```

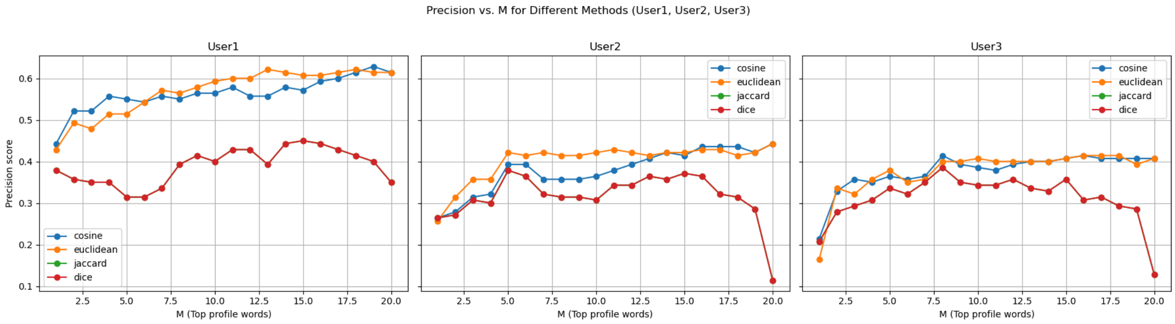
```python
def dice_similarity(a, b):
    if hasattr(a, 'toarray'):
        a = a.toarray()
    if hasattr(b, 'toarray'):
        b = b.toarray()
    a = np.asarray(a).ravel()
    b = np.asarray(b).ravel()
    intersection = np.logical_and(a > 0, b > 0).sum()
    total = (a > 0).sum() + (b > 0).sum()
    return 2 * intersection / total if total > 0 else 0


def rec(user_keywords,user_vector,N,M,method='cosine'):
    test_data_c=test_data.copy()
    topic_list = [topic_keywords[0] for topic_keywords in user_keywords]
    for idx,topic_keywords  in enumerate(user_keywords):

        topic = topic_keywords[0]
        topic_vec=user_vector[idx]
        vectorizer = vectorizers[topic]
        prof_weights = topic_vec.toarray()[0]

        if M<20:
            top_indices = prof_weights.argsort()[::-1][:M]
            topic_vec = np.zeros_like(prof_weights)
            topic_vec[top_indices] = prof_weights[top_indices]
            topic_vec = topic_vec.reshape(1, -1)


        test_vec = vectorizer.transform(test_data_c['Content'])

        if method == 'cosine':
            sims = cosine_similarity(test_vec, topic_vec).flatten()
        elif method == 'euclidean':
            dists = euclidean_distances(test_vec, topic_vec).flatten()
            sims = 1 / (1 + dists)  # 距离越小相似度越大
        elif method == 'jaccard':
            sims = []
            for i in range(test_vec.shape[0]):
                a = test_vec[i].toarray()[0]
                b = topic_vec[0]
                sims.append(jaccard_similarity(a, b))
            sims = np.array(sims)
        elif method == 'dice':
            sims = []
            for i in range(test_vec.shape[0]):
                a = test_vec[i].toarray()[0]
                b = topic_vec[0]
                sims.append(dice_similarity(a, b))
            sims = np.array(sims)
        else:
            raise ValueError(f"Unknown method: {method}")
        test_data_c[f'{topic}_sim_score'] = sims

    sim_cols = [f'{topic}_sim_score' for topic in topic_list]
    sim_matrix = test_data_c[sim_cols].values  # shape=(n_songs, n_topics)

    max_sim = sim_matrix.max(axis=1)
    max_sim_topic_idx = sim_matrix.argmax(axis=1)
    max_sim_topic = [topic_list[i] for i in max_sim_topic_idx]
```

```
    test_data_c['max_sim'] = max_sim
    test_data_c['max_sim_topic'] = max_sim_topic
    topN = test_data_c.nlargest(N, 'max_sim')[['Content','topic','predicted_topi

    liked = (topN['max_sim_topic'] == topN['predicted_topic'])
    true = liked.sum()

    user_interested_topics = set(topic_list)
    relevant_items = test_data_c[test_data_c['predicted_topic'].isin(user_intere
    total_relevant = len(relevant_items)

    precision = true / N
    recall = true / total_relevant if total_relevant > 0 else 0
    f1 = 2 * precision * recall / (precision + recall)

    return precision,recall,f1,topN
```

In [22]:

```
test_data = df.iloc[750:1000]

method=['cosine','euclidean','jaccard','dice']
N=[140]
M=[1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20]
best_f1 = 0
best_result = {}

plot_records = []

users = [
    (user_keywords[0], user_1_vector, "User1"),
    (user_keywords[1], user_2_vector, "User2"),
    (user3_keywords, user_3_vector, "User3")
]

best_precisions=[]

for u_keywords, u_vec, uname in users:
    best=0
    for meth in method:
        for n in N:
            for m in M:
                precision, recall, f1, topN = rec(u_keywords, u_vec, N=n, M=m, m
                plot_records.append({
                    'user': uname,
                    'method': meth,
                    'M': m,
                    'p': precision
                })
                if precision > best:
                    best=precision
    best_precisions.append(best)

df_plot = pd.DataFrame(plot_records)

fig, axes = plt.subplots(1, 3, figsize=(18, 5), sharey=True)

for i, uname in enumerate(["User1", "User2", "User3"]):
    ax = axes[i]
    for meth in method:
        sub = df_plot[(df_plot['user'] == uname) & (df_plot['method'] == meth)]
```

```
        ax.plot(sub['M'], sub['p'], marker='o', label=meth)
    ax.set_title(uname)
    ax.set_xlabel('M (Top profile words)')
    if i == 0:
        ax.set_ylabel('Precision score')
    ax.legend()
    ax.grid(True)

fig.suptitle('Precision vs. M for Different Methods (User1, User2, User3)')
plt.tight_layout(rect=[0, 0, 1, 0.96])
plt.show()
```



The experimental results are shown in the above line graph. I fixed N at 140 (assuming 20 songs are recommended every day, totaling 140 songs for a week), and recommended a total of N songs, the setting is more in line with the actual application scenarios (if there are no suitable new songs for a certain theme this week, the recommendations for that theme will not be displayed). The main evaluation metric of this experiment is Precision, because Recall and F1 will very vary with the choice of N and the number of interest topics in the user profile.

For User1, the effect of using cosine similarity matching is the best; For User2 and User3, both the Euclidean distance and cosine similarity have good performances. When the three users performed the best in Precision, the corresponding M values (the number of high-weight keywords retained in the portrait) were all around 17. It is worth noting that the Precision of User1 is significantly higher than that of User2 and User3. This is mainly because User1 has a richer and more comprehensive interest profile, thus ensuring higher accuracy in system push notifications.

Therefore, I chose M=17 and adopted cosine similarity as the matching method between the user profile and the song.

Part 3

In [23]:
```
df = pd.read_csv('dataset.tsv', sep='\t')
df
```

Out[23]:

	artist_name	track_name	release_date	genre	lyrics	topic
0	loving	the not real lake	2016	rock	awake know go see time clear world mirror worl...	dark
1	incubus	into the summer	2019	rock	shouldn summer pretty build spill ready overfl...	lifestyle
2	reignwolf	hardcore	2016	blues	lose deep catch breath think say try break wal...	sadness
3	tedeschi trucks band	anyhow	2016	blues	run bitter taste take rest feel anchor soul pl...	sadness
4	lukas nelson and promise of the real	if i started over	2017	blues	think think different set apart sober mind sym...	dark
...	...	...	...	...	...	...
1495	ra ra riot	absolutely	2016	rock	year absolutely absolutely absolutely crush ab...	emotion
1496	mat kearney	face to face	2018	rock	breakthrough hours hear truth moments trade fa...	dark
1497	owane	born in space	2018	jazz	look look right catch blue eye own state breat...	dark
1498	nappy roots	blowin' trees	2019	hip hop	nappy root gotta alright flyin dear leave lone...	personal
1499	skillet	stars	2016	rock	speak word life begin tell oceans start motion...	sadness

1500 rows × 6 columns

In [24]:

```
df['Content'] = (
    df['artist_name'].astype(str) + ' ' +
    df['track_name'].astype(str) + ' ' +
    df['release_date'].astype(str) + ' ' +
    df['genre'].astype(str) + ' ' +
    df['lyrics'].astype(str)
)
df = df[['Content', 'topic']]

df['Content_pro'] = df['Content'].apply(lambda x:
    preprocess_text(x, remove_special_chars=True, regex=r"[^\w\s]", strategy='re
                    lowercase=True, stp=False, stemming='lemma')
)
```

```
train_data = df.iloc[:750]
test_data = df.iloc[750:1000]

N=500
vectorizer = CountVectorizer(max_features=N)
X = vectorizer.fit_transform(train_data['Content_pro'])
y = train_data['topic']

mnb = MultinomialNB()
mnb.fit(X, y)
```

```
C:\Users\Aufb\AppData\Local\Temp\ipykernel_30328\2049205918.py:10: SettingWithCop
yWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stabl
e/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['Content_pro'] = df['Content'].apply(lambda x:
```

Out[24]:

```
MultinomialNB

MultinomialNB()
```

In [25]:

```
user_record_idx=[5,7,12,37,54,55,59,48,71,72,77,79,87,88,95,96,116,101,127,256,2
user_likes = df.loc[user_record_idx, ['Content_pro']].copy()

X_pre = vectorizer.fit_transform(user_likes['Content_pro'])
predicted_topics = mnb.predict(X_pre)
user_likes['predicted_topic'] = predicted_topics
user_likes
```

Out[25]:

	Content_pro	predicted_topic
5	tia ray just my luck 2018 jazz yeah happen rea...	sadness
7	thank you scientist the amateur arsonist handb...	dark
12	devin townsend project truth 2016 jazz warn mo...	dark
37	black pistol fire hard luck 2016 blue cold smo...	lifestyle
54	anderson east without you 2018 blue dark live ...	dark
55	keb mo this is my home 2019 blue lupe come mex...	dark
59	taylor mcferrin memory digital 2019 jazz want ...	dark
48	the dear hunter the fire remains 2016 jazz lon...	dark
71	abstract orchestra new day 2018 jazz slide was...	lifestyle
72	wax tailor ecstasy 2017 jazz lock away thing h...	dark
77	tedeschi truck band within you without you 201...	dark
79	henace at dizzys 2019 jazz catch night night d...	personal
87	taylor mcferrin i cant give your time back 201...	sadness
88	romare all night 2016 jazz eglamore valiant kn...	dark
95	the black angel medicine 2017 blue water paint...	lifestyle
96	anderson east learning 2016 blue remember grow...	emotion
116	terence blanchard jackie get out 2017 jazz who...	sadness
101	gramatik native son prequel ft leo napier jena...	sadness
127	jaared dreaming of you 2016 jazz crabb tell lo...	dark
256	the kill black tar 2016 blue invention handsom...	dark
274	melodiesinfonie tokyo 2018 jazz rody soulchyld...	personal
278	black pistol fire wake the riot 2016 blue bite...	dark
296	diana krall blue sky 2017 jazz shin bright thi...	lifestyle
299	danny black high tide 2017 jazz lift hire ligh...	dark
317	joe corfield shimmer 2016 jazz heaven heaven m...	personal
324	jamiroquai automaton 2017 jazz automaton heart...	dark
357	chon dead end 2019 jazz come quarter watch hea...	sadness
550	boogie belgique every time 2016 jazz time good...	lifestyle
552	klischée swing it like roger 2016 jazz catch m...	personal
569	parov stelar soul fever blue 2017 jazz song pl...	emotion
619	brian culbertson color of love 2018 jazz look ...	sadness
614	ivan ave squint 2017 jazz awake stock fridge h...	lifestyle
636	novelist under different welkin 2017 jazz scar...	personal

	Content_pro	predicted_topic
641	reel people i need your lovin 2019 jazz hold h...	personal

In [26]:
```
user_like_pertpioc = []
user_topic=user_likes['predicted_topic'].unique()
for t in user_topic:
    user_like_pertpioc.append( user_likes[user_likes['predicted_topic'] == t]['C
print(user_topic,len(user_like_pertpioc[0]),len(user_like_pertpioc[1]),len(user_
```

```
['sadness' 'dark' 'lifestyle' 'personal' 'emotion'] 6 14 6 6 2
```

In [27]:
```
user_3_vector=[]
for i in range(len(user_like_pertpioc)):
    vectorizer = vectorizers[user_topic[i]]
    X = vectorizer.transform([' '.join(user_like_pertpioc[i])])
    user_3_vector.append(X)
print(user_3_vector[0].shape,user_3_vector[1].shape,user_3_vector[2].shape,user_
```

```
(1, 2280) (1, 4101) (1, 1527) (1, 2919) (1, 876)
```

In [28]:
```
test_data_c=test_data.copy()

M=17
N=140
for idx,topic_vec  in enumerate(user_3_vector):
    topic = user_topic[idx]
    vectorizer = vectorizers[topic]
    prof_weights = topic_vec.toarray()[0]

    top_indices = prof_weights.argsort()[::-1][:M]
    topic_vec = np.zeros_like(prof_weights)
    topic_vec[top_indices] = prof_weights[top_indices]
    topic_vec = topic_vec.reshape(1, -1)

    test_vec = vectorizer.transform(test_data_c['Content'])
    sims = cosine_similarity(test_vec, topic_vec).flatten()
    test_data_c[f'{topic}_sim_score'] = sims

sim_cols = [f'{topic}_sim_score' for topic in user_topic]
sim_matrix = test_data_c[sim_cols].values

max_sim = sim_matrix.max(axis=1)
max_sim_topic_idx = sim_matrix.argmax(axis=1)
max_sim_topic = [user_topic[i] for i in max_sim_topic_idx]

test_data_c['max_sim'] = max_sim
test_data_c['max_sim_topic'] = max_sim_topic
topN = test_data_c.nlargest(N, 'max_sim')[['Content','topic']]
```

In [29]:
```
topN
```

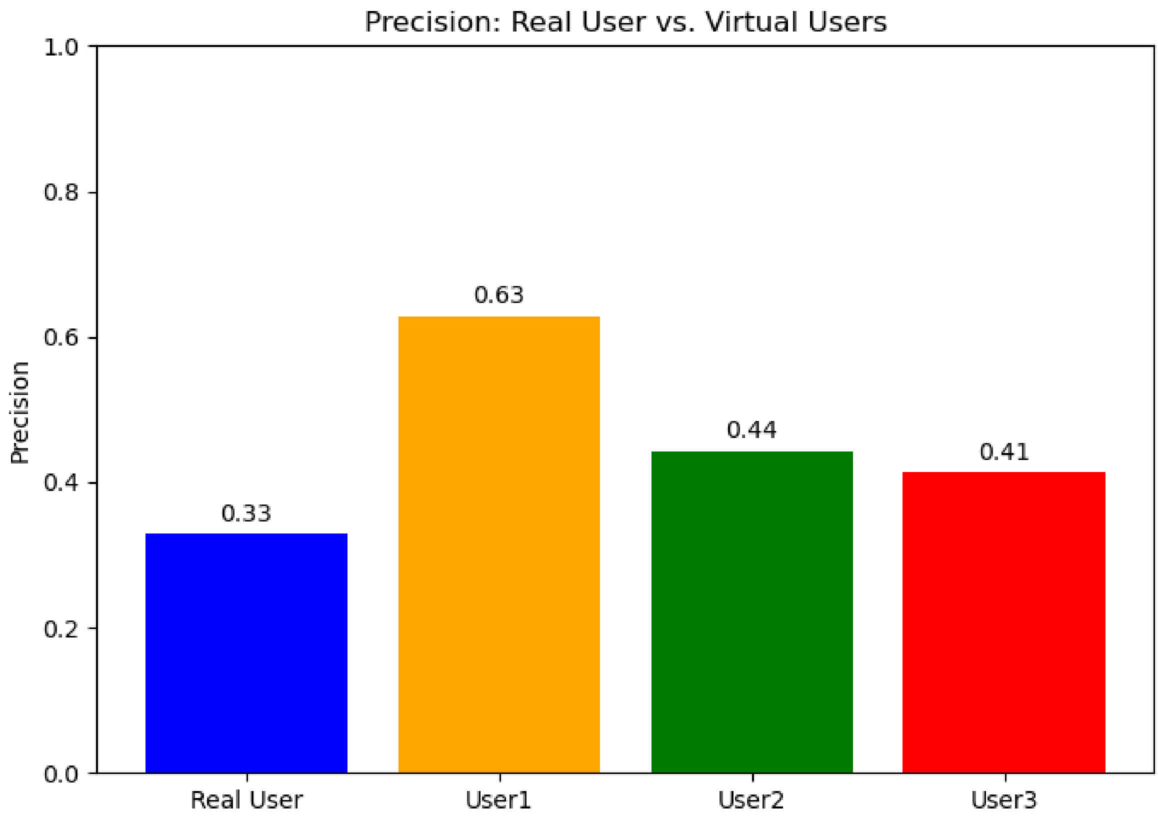
Out[29]:

	Content	topic
907	harry styles sign of the times 2017 pop stop c...	sadness
848	kehlani feels 2019 pop real contemplate bout ...	emotion
755	gary hoey boxcar blues 2016 blues boxcar blue ...	lifestyle
765	iya terra follow your heart (feat. zion thomps...	personal
975	thank you scientist swarm 2019 jazz circle ret...	sadness
...	...	...
815	palace live well 2016 rock sundown slow remind...	personal
997	tesseract smile 2018 jazz calm soothe mechanic...	sadness
998	godsmack under your scars 2018 rock sense thin...	dark
895	he is we i wouldn't mind 2017 rock fall line l...	lifestyle
876	brothers osborne 21 summer 2016 country think ...	lifestyle

140 rows × 2 columns

In [30]:

```
user_like_test=[755,975,794,851,942,790,981,913,864,945,806,862,781,830,840,846,
precision = len(user_like_test) / N

all_precisions = [precision] + best_precisions
labels = ['Real User', 'User1', 'User2', 'User3']
x = np.arange(len(labels))

plt.figure(figsize=(7,5))
bars = plt.bar(x, all_precisions, color=['blue', 'orange', 'green', 'red'])

# 标数值
for rect in bars:
    height = rect.get_height()
    plt.text(rect.get_x() + rect.get_width()/2., height + 0.01,
             f'{height:.2f}', ha='center', va='bottom')

plt.ylim(0, 1)
plt.ylabel('Precision')
plt.title('Precision: Real User vs. Virtual Users')
plt.xticks(x, labels)
plt.tight_layout()
plt.show()
```



I invited a friend who has no knowledge of recommendation systems to participate in this user experiment. During the first three weeks, 140 songs were pushed each week, and the user selected a total of 34 songs that he liked.

The bar chart above compares the Precision metrics of real users and three virtual users. It can be seen that the Precision of real users is significantly lower than that of virtual users. This is mainly because when this user selects the songs he like, he pay more attention to the music types (such as Jazz and Blues) rather than the hashtags. Therefore, the matching degree of the recommendation model constructed based on topic classification for this user is lower than that for the virtual user designed by topic interests.

However, user feedback indicated that, some of the songs pushed still met his taste, and he was overall satisfied with the recommendation results. This indicates that our model has certain generalization ability and robustness, and can provide certain personalized recommendations for users beyond the thematic interests. At the same time, he also discovered that our recommendation system pays more attention to the theme of music rather than the type of music.