

CSE47201 Computer Vision Programming Assignment 1

Problem 2

Import library

In [1]:

```
import cv2
import numpy as np
from tqdm import tqdm
```

Bag-of-words model

In [2]:

```
ls dataset/train
```

```
Faces/          cougar_face/    flamingo/       nautilus/       sunflower/
Faces_easy/     dalmatian/     headphone/      pagoda/          tick/
brontosaurus/   dollar_bill/   lotus/          soccer_ball/     windsor_chair/
car_side/       dragonfly/     menorah/        stop_sign/       yin_yang/
```

Retrieve all categories

In [3]:

```
import os
base_path = "dataset/train"
categories = [name for name in os.listdir(base_path)]
detector = cv2.ORB_create()
```

In [4]:

```
categories
```

Out[4]:

```
['brontosaurus',
 'car_side',
 'cougar_face',
 'dalmatian',
 'dollar_bill',
 'dragonfly',
 'Faces',
 'Faces_easy',
 'flamingo',
 'headphone',
 'lotus',
 'menorah',
 'nautilus',
 'pagoda',
 'soccer_ball',
 'stop_sign',
 'sunflower',
 'tick',
 'windsor_chair',
 'yin_yang']
```

Obtain and compute features of images

In [5]:

```
train_paths = []
train_labels = []
train_features = np.array([])
img_len = 30
count = 0
```

In [6]:

```
# Loop through every images
for idx, category in enumerate(categories):
    dir_path = base_path + '/' + category

    for i in range(img_len):
        # Obtain the image path and labels
        img_path = dir_path + '/' + 'image_%04d.jpg' % (i+1)
        train_paths.append(img_path)
        train_labels.append(idx)

        # Read image
        img = cv2.imread(img_path)
        gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
        # Obtain features
        kpt, desc = detector.detectAndCompute(gray, None)

        # Save images' features
        if train_features.size == 0:
            train_features = np.float32(desc)
        else:
            train_features = np.append(train_features, np.float32(desc), axis=0)

        count+=1
        print('%d/%d - %s - %d feature points are detected\n' % (count, img_len*len(categories), img_path, desc.shape[0]))
```

```
1/600 - dataset/train/brontosaurus/image_0001.jpg - 392 feature points are detected
2/600 - dataset/train/brontosaurus/image_0002.jpg - 427 feature points are detected
3/600 - dataset/train/brontosaurus/image_0003.jpg - 430 feature points are detected
4/600 - dataset/train/brontosaurus/image_0004.jpg - 391 feature points are detected
5/600 - dataset/train/brontosaurus/image_0005.jpg - 445 feature points are detected
6/600 - dataset/train/brontosaurus/image_0006.jpg - 417 feature points are detected
7/600 - dataset/train/brontosaurus/image_0007.jpg - 414 feature points are detected
8/600 - dataset/train/brontosaurus/image_0008.jpg - 331 feature points are detected
9/600 - dataset/train/brontosaurus/image_0009.jpg - 415 feature points are detected
10/600 - dataset/train/brontosaurus/image_0010.jpg - 424 feature points are detected
11/600 - dataset/train/brontosaurus/image_0011.jpg - 330 feature points are detected
12/600 - dataset/train/brontosaurus/image_0012.jpg - 397 feature points are detected
13/600 - dataset/train/brontosaurus/image_0013.jpg - 417 feature points are detected
14/600 - dataset/train/brontosaurus/image_0014.jpg - 446 feature points are detected
15/600 - dataset/train/brontosaurus/image_0015.jpg - 465 feature points are detected
16/600 - dataset/train/brontosaurus/image_0016.jpg - 304 feature points are detected
17/600 - dataset/train/brontosaurus/image_0017.jpg - 220 feature points are detected
18/600 - dataset/train/brontosaurus/image_0018.jpg - 420 feature points are detected
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19/600 - dataset/train/brontosaurus/image_0019.jpg - 424 feature points are detected
20/600 - dataset/train/brontosaurus/image_0020.jpg - 418 feature points are detected
21/600 - dataset/train/brontosaurus/image_0021.jpg - 456 feature points are detected
22/600 - dataset/train/brontosaurus/image_0022.jpg - 293 feature points are detected
23/600 - dataset/train/brontosaurus/image_0023.jpg - 432 feature points are detected
24/600 - dataset/train/brontosaurus/image_0024.jpg - 440 feature points are detected
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27/600 - dataset/train/brontosaurus/image_0027.jpg - 417 feature points are detected
28/600 - dataset/train/brontosaurus/image_0028.jpg - 433 feature points are detected
29/600 - dataset/train/brontosaurus/image_0029.jpg - 340 feature points are detected
30/600 - dataset/train/brontosaurus/image_0030.jpg - 374 feature points are detected
31/600 - dataset/train/car_side/image_0001.jpg - 430 feature points are detected
32/600 - dataset/train/car_side/image_0002.jpg - 420 feature points are detected
33/600 - dataset/train/car_side/image_0003.jpg - 424 feature points are detected
34/600 - dataset/train/car_side/image_0004.jpg - 378 feature points are detected
35/600 - dataset/train/car_side/image_0005.jpg - 411 feature points are detected
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37/600 - dataset/train/car_side/image_0007.jpg - 420 feature points are detected
38/600 - dataset/train/car_side/image_0008.jpg - 383 feature points are detected
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61/600 - dataset/train/cougar_face/image_0001.jpg - 483 feature points are detected
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181/600 - dataset/train/Faces/image_0001.jpg - 492 feature points are detected
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211/600 - dataset/train/Faces_easy/image_0001.jpg - 460 feature points are detected
212/600 - dataset/train/Faces_easy/image_0002.jpg - 445 feature points are detected
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241/600 - dataset/train/flamingo/image_0001.jpg - 444 feature points are detected
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269/600 - dataset/train/flamingo/image_0029.jpg - 417 feature points are detected
270/600 - dataset/train/flamingo/image_0030.jpg - 477 feature points are detected

271/600 - dataset/train/headphone/image_0001.jpg - 234 feature points are detected
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292/600 - dataset/train/headphone/image_0022.jpg - 285 feature points are detected
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294/600 - dataset/train/headphone/image_0024.jpg - 412 feature points are detected
295/600 - dataset/train/headphone/image_0025.jpg - 463 feature points are detected
296/600 - dataset/train/headphone/image_0026.jpg - 417 feature points are detected
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298/600 - dataset/train/headphone/image_0028.jpg - 414 feature points are detected
299/600 - dataset/train/headphone/image_0029.jpg - 390 feature points are detected
300/600 - dataset/train/headphone/image_0030.jpg - 346 feature points are detected
301/600 - dataset/train/lotus/image_0001.jpg - 440 feature points are detected
302/600 - dataset/train/lotus/image_0002.jpg - 464 feature points are detected
303/600 - dataset/train/lotus/image_0003.jpg - 432 feature points are detected
304/600 - dataset/train/lotus/image_0004.jpg - 340 feature points are detected
305/600 - dataset/train/lotus/image_0005.jpg - 426 feature points are detected
306/600 - dataset/train/lotus/image_0006.jpg - 410 feature points are detected

307/600 - dataset/train/lotus/image_0007.jpg - 455 feature points are detected

308/600 - dataset/train/lotus/image_0008.jpg - 422 feature points are detected

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315/600 - dataset/train/lotus/image_0015.jpg - 399 feature points are detected

316/600 - dataset/train/lotus/image_0016.jpg - 324 feature points are detected

317/600 - dataset/train/lotus/image_0017.jpg - 365 feature points are detected

318/600 - dataset/train/lotus/image_0018.jpg - 444 feature points are detected

319/600 - dataset/train/lotus/image_0019.jpg - 429 feature points are detected

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321/600 - dataset/train/lotus/image_0021.jpg - 437 feature points are detected

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328/600 - dataset/train/lotus/image_0028.jpg - 430 feature points are detected

329/600 - dataset/train/lotus/image_0029.jpg - 356 feature points are detected

330/600 - dataset/train/lotus/image_0030.jpg - 395 feature points are detected

331/600 - dataset/train/menorah/image_0001.jpg - 478 feature points are detected

332/600 - dataset/train/menorah/image_0002.jpg - 485 feature points are detected

333/600 - dataset/train/menorah/image_0003.jpg - 421 feature points are detected

334/600 - dataset/train/menorah/image_0004.jpg - 492 feature points are detected

335/600 - dataset/train/menorah/image_0005.jpg - 482 feature points are detected

336/600 - dataset/train/menorah/image_0006.jpg - 444 feature points are detected

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352/600 - dataset/train/menorah/image_0022.jpg - 161 feature points are detected
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361/600 - dataset/train/nautilus/image_0001.jpg - 464 feature points are detected
362/600 - dataset/train/nautilus/image_0002.jpg - 478 feature points are detected
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364/600 - dataset/train/nautilus/image_0004.jpg - 439 feature points are detected
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390/600 - dataset/train/nautilus/image_0030.jpg - 458 feature points are detected
391/600 - dataset/train/pagoda/image_0001.jpg - 384 feature points are detected
392/600 - dataset/train/pagoda/image_0002.jpg - 467 feature points are detected
393/600 - dataset/train/pagoda/image_0003.jpg - 462 feature points are detected
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421/600 - dataset/train/soccer_ball/image_0001.jpg - 417 feature points are detected

422/600 - dataset/train/soccer_ball/image_0002.jpg - 339 feature points are detected

423/600 - dataset/train/soccer_ball/image_0003.jpg - 302 feature points are detected

424/600 - dataset/train/soccer_ball/image_0004.jpg - 370 feature points are detected

425/600 - dataset/train/soccer_ball/image_0005.jpg - 434 feature points are detected

426/600 - dataset/train/soccer_ball/image_0006.jpg - 351 feature points are detected

427/600 - dataset/train/soccer_ball/image_0007.jpg - 401 feature points are detected

428/600 - dataset/train/soccer_ball/image_0008.jpg - 263 feature points are detected

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431/600 - dataset/train/soccer_ball/image_0011.jpg - 391 feature points are detected

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450/600 - dataset/train/soccer_ball/image_0030.jpg - 433 feature points are detected

451/600 - dataset/train/stop_sign/image_0001.jpg - 428 feature points are detected
452/600 - dataset/train/stop_sign/image_0002.jpg - 254 feature points are detected
453/600 - dataset/train/stop_sign/image_0003.jpg - 453 feature points are detected
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481/600 - dataset/train/sunflower/image_0001.jpg - 411 feature points are detected
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539/600 - dataset/train/tick/image_0029.jpg - 460 feature points are detected

540/600 - dataset/train/tick/image_0030.jpg - 434 feature points are detected

541/600 - dataset/train/windsor_chair/image_0001.jpg - 407 feature points are detected

542/600 - dataset/train/windsor_chair/image_0002.jpg - 400 feature points are detected

543/600 - dataset/train/windsor_chair/image_0003.jpg - 456 feature points are detected

544/600 - dataset/train/windsor_chair/image_0004.jpg - 430 feature points are detected

545/600 - dataset/train/windsor_chair/image_0005.jpg - 408 feature points are detected

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570/600 - dataset/train/windsor_chair/image_0030.jpg - 294 feature points are detected
571/600 - dataset/train/yin_yang/image_0001.jpg - 273 feature points are detected
572/600 - dataset/train/yin_yang/image_0002.jpg - 332 feature points are detected
573/600 - dataset/train/yin_yang/image_0003.jpg - 372 feature points are detected
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593/600 - dataset/train/yin_yang/image_0023.jpg - 439 feature points are detected
594/600 - dataset/train/yin_yang/image_0024.jpg - 358 feature points are detected

595/600 - dataset/train/yin_yang/image_0025.jpg - 373 feature points are detected
596/600 - dataset/train/yin_yang/image_0026.jpg - 409 feature points are detected
597/600 - dataset/train/yin_yang/image_0027.jpg - 355 feature points are detected
598/600 - dataset/train/yin_yang/image_0028.jpg - 342 feature points are detected
599/600 - dataset/train/yin_yang/image_0029.jpg - 435 feature points are detected
600/600 - dataset/train/yin_yang/image_0030.jpg - 475 feature points are detected

SVM Classifier implementation

In [7]:

```
# SVM image classifier
class Classifier:

    # Constructor
    # code_words: the number of codewords
    # base_path: path contains the data
    def __init__(self, code_words, base_path):
        # Load the dictionary file
        self.dictionary = np.load("dictionary.npy")
        self.dictionary_size = code_words

        # Create instance of KNN algorithm
        self.knn = cv2.ml.KNearest_create()

        # Obtain images path
        self.train_paths = []
        self.train_labels = []
        for idx, category in enumerate(categories):
            dir_path = base_path + '/' + category
            for i in range(img_len):
                img_path = dir_path + '/' + 'image_%04d.jpg' % (i+1)

                # Store labels and path
                self.train_paths.append(img_path)
                self.train_labels.append(idx)

        # Create histogram of codewords
        self.hists = np.float32(np.zeros((len(self.train_paths), self.dictionary_size)))

        # Create SVM
        self.svm = cv2.ml.SVM_create()

        # Start training KNN
        def train_knn(self):
            # Train KNN
            self.knn.train(self.dictionary, cv2.ml.ROW_SAMPLE, np.float32(range(self.dictionary_size)))

            # Loop to update histogram of codewords
            for i, path in enumerate(self.train_paths):
                # Read images
                img = cv2.imread(path)
                gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
                # Obtain features
                kpt, desc = detector.detectAndCompute(gray, None)

                # Clustering
                ret, result, neighbours, dist = self.knn.findNearest(np.float32(desc), k=1)
                hist, bins = np.histogram(np.int32(result), bins=range(self.dictionary_size
+ 1))

            # Update histogram
```

```

        self.hists[i, :] = np.float32(hist) / np.float32(np.sum(hist))

# Train SVM
# file_name=place to save the model
def fit(self, file_name="svmmodel.xml"):
    self.train_knn()
    svm_model_file = file_name
    # Train SVM
    self.svm.train(self.hists, cv2.ml.ROW_SAMPLE, np.array(self.train_labels))
    # Save SVM
    self.svm.save(svm_model_file)

# Get prediction
def predict(self, test_desc):
    return self.svm.predict(test_desc)

# Get prediction
# img_path=Path to the image
def get_prediction(self, img_path):
    # Read image
    img = cv2.imread(img_path)
    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

    # Obtain features
    kpt, desc = detector.detectAndCompute(gray, None)
    ret, result, neighbours, dist = self.knn.findNearest(np.float32(desc), k=1)

    # Get histogram
    hist1, bins = np.histogram(np.int32(result), bins=range(self.dictionary_size + 1
))

    test_desc = np.float32(np.zeros((1, self.dictionary_size)))
    test_desc[0, :] = np.float32(hist1) / np.float32(np.sum(hist1))

    # Predict the category
    ret, result = self.predict(test_desc)
    return result

```

In [8]:

```

# Create an instance of Classifier with other codewords and kernels
def svm_classifier(code_words, kernel = None):
    # Dictionary path
    dict_file = "dictionary.npy"
    criteria = (cv2.TERM_CRITERIA_EPS + cv2.TERM_CRITERIA_MAX_ITER, 10, 0.1)

    # Start K-means algorithm
    ret, label, dictionary = cv2.kmeans(train_features, code_words, None, criteria, 10,
cv2.KMEANS_RANDOM_CENTERS)

    # Save the dictionary
    np.save(dict_file, dictionary)

    # Create the model
    model = Classifier(code_words=code_words, base_path=base_path)

    # If a kernel is set
    if kernel is not None:
        model.svm.setKernel(kernel)

    # Train SVM
    model.fit()

    return model

```

Accuracy computation

In [9]:

```

# Obtain training accuracy

```

```

# Obtain training accuracy
def get_train_accuracy(model):
    total_sample, total_correct = 0, 0

    # Loop through every category
    for idx, category in enumerate(categories):
        dir_path = "dataset/train" + '/' + category

        # Loop through every sample of that category
        for i in range(img_len):
            img_path = dir_path + '/' + 'image_%04d.jpg' % (i+1)
            total_sample += 1

            # If the prediction is correct, increase total_correct by 1
            total_correct += int(idx == model.get_prediction(img_path)[0, 0])

    # Return the accuracy
    return total_correct / total_sample

```

In [10]:

```

# Obtain training accuracy
def get_test_accuracy(model):
    total_sample, total_correct = 0, 0

    # Loop through every category
    for idx, category in enumerate(categories):
        dir_path = "dataset/test" + '/' + category

        # Loop through every sample of that category
        for i in range(30, 35):
            img_path = dir_path + '/' + 'image_%04d.jpg' % (i+1)
            total_sample += 1

            # If the prediction is correct, increase total_correct by 1
            total_correct += int(idx == model.get_prediction(img_path)[0, 0])

    # Return the accuracy
    return total_correct / total_sample

```

Hyperparameters

In [11]:

```

train_acc = []
test_acc = []
MAX_CODEWORDS = 500

```

Train SVM with different codewords

In [12]:

```

for code_words in range(20, MAX_CODEWORDS + 1, 20):
    # Create model with codewords
    model = svm_classifier(code_words)

    # Save accuracies
    train_acc.append(get_train_accuracy(model))
    test_acc.append(get_test_accuracy(model))

    # Monitor the process
    print(f"{code_words} code words accuracy: train({train_acc[-1]:.6f})\t test({test_acc[-1]:.6f})")

```

20 code words accuracy: train(0.276667) test(0.250000)
40 code words accuracy: train(0.298333) test(0.280000)
60 code words accuracy: train(0.350000) test(0.310000)
80 code words accuracy: train(0.361667) test(0.300000)
100 code words accuracy: train(0.381667) test(0.330000)
120 code words accuracy: train(0.378333) test(0.350000)

```

140 code words accuracy: train(0.378333) test(0.370000)
160 code words accuracy: train(0.411667) test(0.320000)
180 code words accuracy: train(0.393333) test(0.330000)
200 code words accuracy: train(0.391667) test(0.340000)
220 code words accuracy: train(0.415000) test(0.380000)
240 code words accuracy: train(0.411667) test(0.340000)
260 code words accuracy: train(0.416667) test(0.390000)
280 code words accuracy: train(0.426667) test(0.400000)
300 code words accuracy: train(0.428333) test(0.360000)
320 code words accuracy: train(0.445000) test(0.400000)
340 code words accuracy: train(0.416667) test(0.390000)
360 code words accuracy: train(0.466667) test(0.390000)
380 code words accuracy: train(0.445000) test(0.340000)
400 code words accuracy: train(0.461667) test(0.380000)
420 code words accuracy: train(0.468333) test(0.400000)
440 code words accuracy: train(0.475000) test(0.370000)
460 code words accuracy: train(0.471667) test(0.370000)
480 code words accuracy: train(0.460000) test(0.400000)
500 code words accuracy: train(0.493333) test(0.380000)

```

Plot the accuracy

In [13]:

```

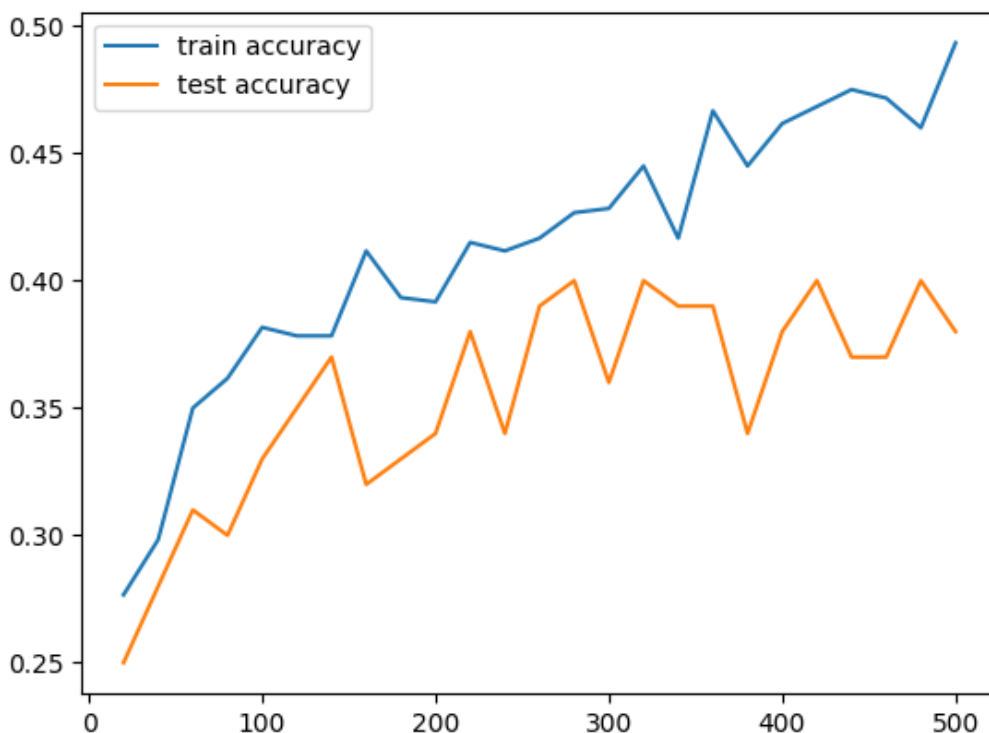
import matplotlib.pyplot as plt

plt.plot(range(20, MAX_CODEWORDS + 1, 20), train_acc, label="train accuracy")
plt.plot(range(20, MAX_CODEWORDS + 1, 20), test_acc, label="test accuracy")
plt.legend(loc="upper left")

```

Out[13]:

<matplotlib.legend.Legend at 0x7f10832e5d30>



As we can see from the graph, the accuracy is increasing a long with the number of codewords.

Both train and test accuracy are trending upward. However, test accuracy starts to converge to a point near 40%.

Train SVM with histogram intersection kernel

In [14]:

```

train_acc = []

```

```
train_acc = []  
test_acc = []
```

In [15]:

```
for code_words in range(20, MAX_CODEWORDS + 1, 20):  
    # Create model with codewords and kernel  
    model = svm_classifier(code_words, cv2.ml.SVM_INTER)  
  
    # Save accuracies  
    train_acc.append(get_train_accuracy(model))  
    test_acc.append(get_test_accuracy(model))  
  
    # Monitor the result  
    print(f"{code_words} code words accuracy: train({train_acc[-1]:.6f})\t test({test_acc[-1]:.6f})")
```

```
20 code words accuracy: train(0.490000)    test(0.400000)  
40 code words accuracy: train(0.583333)    test(0.460000)  
60 code words accuracy: train(0.643333)    test(0.470000)  
80 code words accuracy: train(0.688333)    test(0.480000)  
100 code words accuracy: train(0.760000)    test(0.510000)  
120 code words accuracy: train(0.776667)    test(0.480000)  
140 code words accuracy: train(0.810000)    test(0.540000)  
160 code words accuracy: train(0.838333)    test(0.540000)  
180 code words accuracy: train(0.853333)    test(0.550000)  
200 code words accuracy: train(0.845000)    test(0.560000)  
220 code words accuracy: train(0.868333)    test(0.550000)  
240 code words accuracy: train(0.888333)    test(0.550000)  
260 code words accuracy: train(0.908333)    test(0.590000)  
280 code words accuracy: train(0.903333)    test(0.570000)  
300 code words accuracy: train(0.935000)    test(0.580000)  
320 code words accuracy: train(0.908333)    test(0.560000)  
340 code words accuracy: train(0.933333)    test(0.580000)  
360 code words accuracy: train(0.938333)    test(0.630000)  
380 code words accuracy: train(0.945000)    test(0.620000)  
400 code words accuracy: train(0.953333)    test(0.580000)  
420 code words accuracy: train(0.948333)    test(0.640000)  
440 code words accuracy: train(0.948333)    test(0.550000)  
460 code words accuracy: train(0.960000)    test(0.600000)  
480 code words accuracy: train(0.971667)    test(0.650000)  
500 code words accuracy: train(0.963333)    test(0.590000)
```

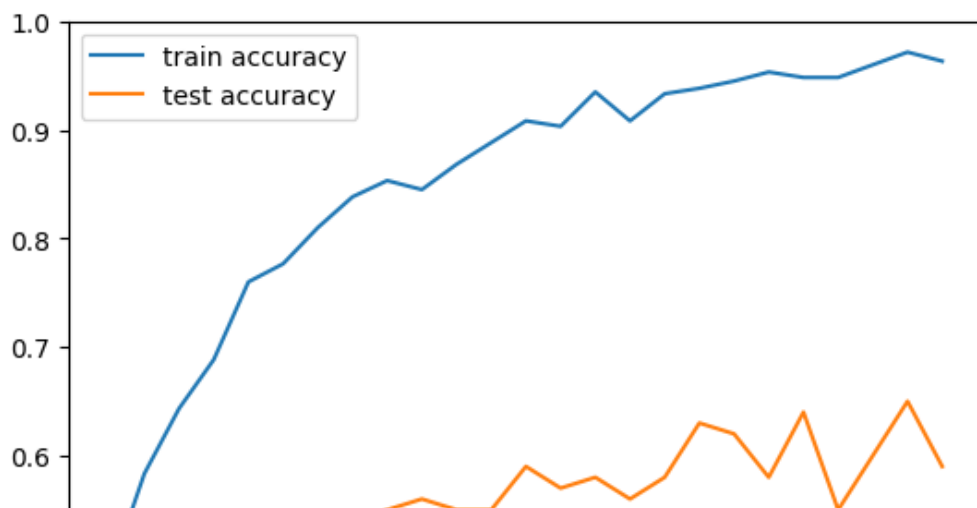
Plot the accuracy

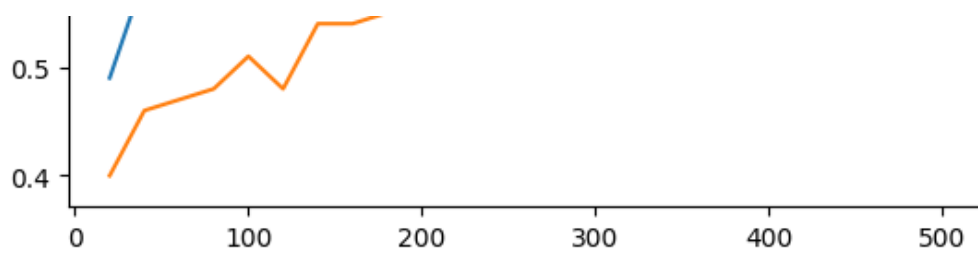
In [16]:

```
plt.plot(range(20, MAX_CODEWORDS + 1, 20), train_acc, label="train accuracy")  
plt.plot(range(20, MAX_CODEWORDS + 1, 20), test_acc, label="test accuracy")  
plt.legend(loc="upper left")
```

Out[16]:

<matplotlib.legend.Legend at 0x7f107bb08220>





As we can see from the graph, the accuracy is increasing a long with the number of codewords.

Both train and test accuracy are tranding upward. However, test accuracy starts to converge at around 60%.

Comparing with the default kernel, histogram intersection kernel yields a better accuracy, both for train and test dataset.