

```
In [1]: import warnings
warnings.filterwarnings('ignore')
```

```
In [2]: import numpy as np
import pandas as pd

from tqdm import tqdm
from joblib import Parallel, delayed
from os import cpu_count
from svmutil import *
```

```
In [3]: def problem15():
    trainY, trainX = svm_read_problem("satimage.scale")
    df = pd.DataFrame(trainX).fillna(0)
    trainX, trainY = df.to_numpy(), [1 if i == 3 else -1 for i in trainY]
    model = svm_train(trainY, trainX, "-s 0 -t 0 -c 10")
    index = [i-1 for i in model.get_sv_indices()]
    anyn = np.array(model.get_sv_coef())
    zn = trainX[index]
    print(f"||w|| is {np.linalg.norm(np.dot(anyn.T, zn)):.1f}")
```

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problem15()
```

||w|| is 8.5

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In [4]: def problem16():
    trainY, trainX = svm_read_problem("satimage.scale")
    df = pd.DataFrame(trainX).fillna(0)
    for number in range(1, 6):
        X, Y = df.to_numpy(), [1 if i == number else -1 for i in trainY]
        model = svm_train(Y, X, "-s 0 -t 1 -d 2 -c 10")
        p_label, p_acc, p_val = svm_predict(Y, X, model, "-q")
        ACC, MSE, SCC = evaluations(Y, p_label)
        print(f"Ein of \"{number}\" versus \"not {number}\" is {100 - ACC:.2f}%")
```

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problem16()
```

```
Ein of "1" versus "not 1" is 1.62%
Ein of "2" versus "not 2" is 0.70%
Ein of "3" versus "not 3" is 4.19%
Ein of "4" versus "not 4" is 9.36%
Ein of "5" versus "not 5" is 4.35%
```

```
In [5]: def problem17():
    trainY, trainX = svm_read_problem("satimage.scale")
    df = pd.DataFrame(trainX).fillna(0)
    for number in range(1, 6):
        X, Y = df.to_numpy(), [1 if i == number else -1 for i in trainY]
        model = svm_train(Y, X, "-s 0 -t 1 -d 2 -c 10")
        sv = model.get_nr_sv()
        print(
            f"The number of support vector(s) for \"{number}\" versus \"not {number}\"
```

```
problem17()
```

```
The number of support vector(s) for "1" versus "not 1" is 520
The number of support vector(s) for "2" versus "not 2" is 165
The number of support vector(s) for "3" versus "not 3" is 750
```

The number of support vector(s) for "4" versus "not 4" is 859  
 The number of support vector(s) for "5" versus "not 5" is 690

```
In [6]: def problem18():
        trainY, trainX = svm_read_problem("satimage.scale")
        X, Y = trainX, [1 if i == 6 else -1 for i in trainY]

        testY, testX = svm_read_problem("satimage.scale.t")
        testY = [1 if i == 6 else -1 for i in testY]

        for cost in [0.01, 0.1, 1, 10, 100]:
            model = svm_train(Y, X, f"-s 0 -t 2 -g 10 -c {cost}")
            p_label, p_acc, p_val = svm_predict(testY, testX, model, "-q")
            ACC, MSE, SCC = evaluations(testY, p_label)
            print(f"Eout of C={cost} is {100 - ACC:.2f}%")

        problem18()
```

Eout of C=0.01 is 23.50%  
 Eout of C=0.1 is 16.35%  
 Eout of C=1 is 10.65%  
 Eout of C=10 is 9.70%  
 Eout of C=100 is 9.70%

```
In [7]: def problem19():
        trainY, trainX = svm_read_problem("satimage.scale")
        X, Y = trainX, [1 if i == 6 else -1 for i in trainY]

        testY, testX = svm_read_problem("satimage.scale.t")
        testY = [1 if i == 6 else -1 for i in testY]

        for gamma in [0.1, 1, 10, 100, 1000]:
            model = svm_train(Y, X, f"-s 0 -t 2 -g {gamma} -c 0.1")
            p_label, p_acc, p_val = svm_predict(testY, testX, model, "-q")
            ACC, MSE, SCC = evaluations(testY, p_label)
            print(f"Eout of gamma={gamma} is {100 - ACC:.2f}%")

        problem19()
```

Eout of gamma=0.1 is 9.85%  
 Eout of gamma=1 is 7.00%  
 Eout of gamma=10 is 16.35%  
 Eout of gamma=100 is 23.50%  
 Eout of gamma=1000 is 23.50%

```
In [8]: def problem20():
        resultDict = {0.1: [], 1: [], 10: [], 100: [], 1000: []}

        trainY, trainX = svm_read_problem("satimage.scale")
        X, Y = pd.DataFrame(trainX).fillna(0), pd.Series(
            [1 if i == 6 else -1 for i in trainY])

        for gamma in [0.1, 1, 10, 100, 1000]:
            for _ in tqdm(range(1000)):
                indexes = np.random.choice(X.index, size=200)
                learnX, learnY = X.drop(indexes).to_numpy(), Y.drop(indexes).to_numpy()
                valX, valY = X.loc[indexes].to_numpy(), Y.loc[indexes].to_numpy()

                model = svm_train(learnY, learnX, f"-s 0 -t 2 -g {gamma} -c 0.1")
                p_label, p_acc, p_val = svm_predict(valY, valX, model, "-q")
```

```
ACC, MSE, SCC = evaluations(valY, p_label)
resultDict[gamma].append(ACC)
```

```
print("\n")
for gamma, score in resultDict.items():
    print(f"Gamma={gamma}, Eval is {100 - sum(score) / len(score):.2f}%")
```

```
problem20()
```

```
100%|██████████| 1000/1000 [08:48<00:00, 1.89it/s]
100%|██████████| 1000/1000 [09:52<00:00, 1.69it/s]
100%|██████████| 1000/1000 [24:34<00:00, 1.47s/it]
100%|██████████| 1000/1000 [29:13<00:00, 1.75s/it]
100%|██████████| 1000/1000 [33:41<00:00, 2.02s/it]
```

```
Gamma=0.1, Eval is 8.22%
Gamma=1, Eval is 7.02%
Gamma=10, Eval is 16.49%
Gamma=100, Eval is 23.34%
Gamma=1000, Eval is 23.45%
```