a1_4

October 3, 2025

[1]:
```python
# ---
# jupyter:
#   jupytext:
#     text_representation:
#       extension: .py
#       format_name: percent
#       format_version: '1.3'
#       jupytext_version: 1.16.7
#   kernelspec:
#     display_name: Python (ML25_assignments)
#     language: python
#     name: ml25
# ---

# %% [markdown]
# # 4 Model Selection (optional)

# %%
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import KFold
from sklearn.metrics import accuracy_score
from sklearn.model_selection import KFold
# %load_ext autoreload
# %autoreload 2

from a01_helper import *
from a01_functions import nb_train, nb_predict
```

[2]:
```python
# %%
# To create folds, you can use:
K = 5
Kf = KFold(n_splits=K, shuffle=True)
for i_train, i_test in Kf.split(X):
    # code here is executed K times, once per test fold
    # i_train has the row indexes of X to be used for training
    # i_test has the row indexes of X to be used for testing
    print(
```

```
        "Fold has {:d} training points and {:d} test points".format(
            len(i_train), len(i_test)
        )
    )
```

```
Fold has 48000 training points and 12000 test points
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```

[3]:
```python
# %%
# Use cross-validation to find a good value of alpha. Also plot the obtained
# accuracy estimate (estimated from CV, i.e., without touching test data) as a
# function of alpha.
# YOUR CODE HERE

# Choose whether to run CV on the small sample (fast) or full MNIST (slow).
# For initial experimentation use use_sample=True. For final run set False.
use_sample = True

if use_sample:
    X_cv = X_s.copy()
    y_cv = y_s.copy()
    print("Using sampled data (fast).")
else:
    X_cv = X.copy()
    y_cv = y.copy()
    print("Using full data (slow).")
```

```
Using sampled data (fast).
```

[4]:
```python
# K-Fold setup (you already declared K above; reuse or set here)
K = 5
kf = KFold(n_splits=K, shuffle=True, random_state=0)

# Alphas to try: include small integers and a few larger values.
# You can change or extend this list.
alphas = [1, 2, 5, 10, 50, 100]

# Storage for results
mean_acc = []
std_acc = []
all_fold_acc = np.zeros((len(alphas), K))

# CV loop
for ia, alpha in enumerate(alphas):
    fold_idx = 0
```

```python
    print(f"\nAlpha = {alpha}:")
    for train_idx, test_idx in kf.split(X_cv):
        Xtr, ytr = X_cv[train_idx], y_cv[train_idx]
        Xte, yte = X_cv[test_idx], y_cv[test_idx]

        # Train and predict
        model = nb_train(Xtr, ytr, alpha=alpha)
        pred = nb_predict(model, Xte)
        yhat = pred["yhat"]

        acc = accuracy_score(yte, yhat)
        all_fold_acc[ia, fold_idx] = acc
        print(f"  Fold {fold_idx+1}/{K} accuracy: {acc:.4f}")
        fold_idx += 1

    mean_acc.append(all_fold_acc[ia].mean())
    std_acc.append(all_fold_acc[ia].std())
    print(f"  -> mean acc: {mean_acc[-1]:.4f}, std: {std_acc[-1]:.4f}")

mean_acc = np.array(mean_acc)
std_acc = np.array(std_acc)
```

```
Alpha = 1:
  Fold 1/5 accuracy: 0.0750
  Fold 2/5 accuracy: 0.1350
  Fold 3/5 accuracy: 0.0800
  Fold 4/5 accuracy: 0.0800
  Fold 5/5 accuracy: 0.1300
  -> mean acc: 0.1000, std: 0.0266

Alpha = 2:
  Fold 1/5 accuracy: 0.2600
  Fold 2/5 accuracy: 0.5750
  Fold 3/5 accuracy: 0.4300
```

```
/Users/marmee/Desktop/Data Science/Semester 5/Machine
Learning/Assignment/a01-nb/a01_functions.py:77: RuntimeWarning: divide by zero
encountered in log
  return dict(logpriors=np.log(priors), logcls=np.log(cls))
/Users/marmee/Desktop/Data Science/Semester 5/Machine
Learning/Assignment/a01-nb/a01_helper.py:136: RuntimeWarning: invalid value
encountered in subtract
  return offset + np.log(np.sum(np.exp(x - offset), axis=0))
/Users/marmee/Desktop/Data Science/Semester 5/Machine
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```
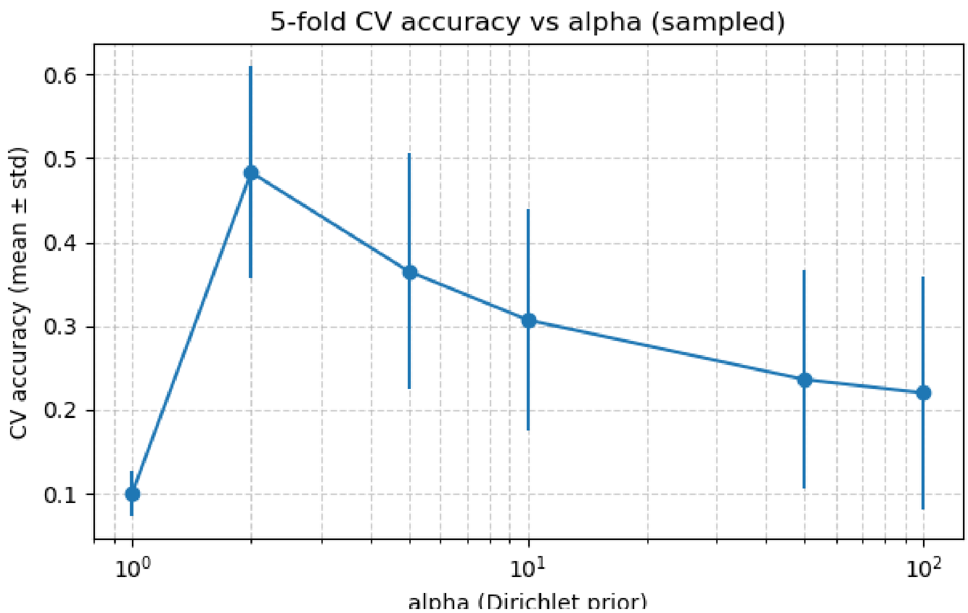

```
  Fold 4/5 accuracy: 0.6100
  Fold 5/5 accuracy: 0.5400
  -> mean acc: 0.4830, std: 0.1268

Alpha = 5:
  Fold 1/5 accuracy: 0.1250
  Fold 2/5 accuracy: 0.4550
  Fold 3/5 accuracy: 0.3350
  Fold 4/5 accuracy: 0.5450
  Fold 5/5 accuracy: 0.3650
  -> mean acc: 0.3650, std: 0.1407

Alpha = 10:
  Fold 1/5 accuracy: 0.1000
  Fold 2/5 accuracy: 0.3550
  Fold 3/5 accuracy: 0.3000
  Fold 4/5 accuracy: 0.5100
  Fold 5/5 accuracy: 0.2700
  -> mean acc: 0.3070, std: 0.1325
```

```
Alpha = 50:
  Fold 1/5 accuracy: 0.0600
  Fold 2/5 accuracy: 0.2850
  Fold 3/5 accuracy: 0.1850
  Fold 4/5 accuracy: 0.4550
  Fold 5/5 accuracy: 0.1950
  -> mean acc: 0.2360, std: 0.1309

Alpha = 100:
  Fold 1/5 accuracy: 0.0550
  Fold 2/5 accuracy: 0.2700
  Fold 3/5 accuracy: 0.1350
  Fold 4/5 accuracy: 0.4600
  Fold 5/5 accuracy: 0.1800
  -> mean acc: 0.2200, std: 0.1387
```

[5]:

```python
# Plot results
plt.figure(figsize=(7,4))
plt.errorbar(alphas, mean_acc, yerr=std_acc, marker='o', linestyle='-')
plt.xscale('log')  # alpha is a hyperparameter spanning multiple scales; log␣
 ↪scale helps
plt.xlabel('alpha (Dirichlet prior)')
plt.ylabel('CV accuracy (mean ± std)')
plt.title(f'{K}-fold CV accuracy vs alpha {"(sampled)" if use_sample else␣
 ↪"(full)"}')
plt.grid(True, which='both', ls='--', alpha=0.6)
plt.show()
```



[6]:

```python
# Print best alpha (highest mean CV accuracy)
best_idx = np.argmax(mean_acc)
print(f"Best alpha (by mean CV acc): {alphas[best_idx]} with mean acc␣
↪{mean_acc[best_idx]:.4f} ± {std_acc[best_idx]:.4f}")
```

```
Best alpha (by mean CV acc): 2 with mean acc 0.4830 ± 0.1268
```