

Bias and variance of SVMs

Fraida Fund

In this notebook, we will explore the bias and variance of SVM models, and see how we can tune this tradeoff.

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd

from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV, train_test_split
from sklearn.metrics import accuracy_score

from tqdm import tqdm

from sklearn.datasets import make_blobs
```

Regularization level

Suppose we want to train a model to classify two “blobs” of data.

```
n_repeat = 100
n_test = 500
n_train = 100
sigma = 0.8
cluster_centers = np.array([[ -1, 1], [ 2, 2]])
```

```
y_predict = np.zeros((n_test, n_repeat, 2))
```

```
x_test, y_test = make_blobs(n_samples=n_test, centers=cluster_centers,
                             random_state=0, cluster_std=sigma)
```

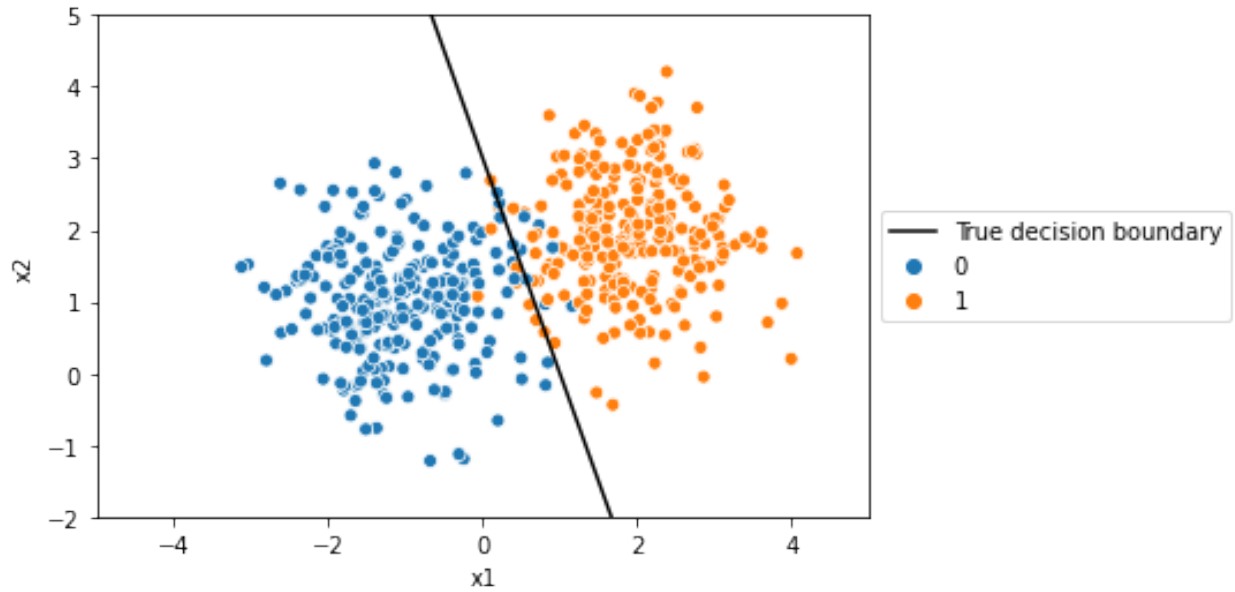
```
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test);
```

```
plt.xlabel("x1");
plt.ylabel("x2");
plt.xlim(-5,5);
plt.ylim(-2,5);
```

get the true decision boundary

```
mid = [cluster_centers[:,0].mean(), cluster_centers[:,1].mean()]
slp = -1.0/((cluster_centers[1,1]-cluster_centers[0,1])/(cluster_centers[1,0]-cluster_centers[0,0]))
b = mid[1]-slp*mid[0]
x_true = np.arange(-5,5)
y_true = slp*x_true + b
sns.lineplot(x=x_true, y=y_true, color='black', label="True decision boundary")

plt.legend(loc='center left', bbox_to_anchor=(1, 0.5), ncol=1);
```



Which will have greater bias, and which will have greater variance?

- **Model A:** Linear SVM with $C = 0.01$
- **Model B:** Linear SVM with $C = 100$

Note: here is C in the SVM problem:

$$\begin{aligned} & \underset{w, \xi}{\text{minimize}} && \frac{1}{2} \sum_{j=1}^p w_j^2 + C \sum_{i=1}^n \epsilon_i \\ & \text{subject to} && y_i(w_0 + \sum_{j=1}^p w_j x_{ij}) \geq 1 - \epsilon_i, \quad \forall i \\ & && \epsilon_i \geq 0, \quad \forall i \end{aligned}$$

The greater the value of C , the more heavily the “margin violators” penalize the overall objective function. Therefore,

- If C is large, the margin must be narrow (with few “margin violators”).
- If C is small, the margin may be wider (with more “margin violators”).

```
Z_sim = np.zeros((40000, n_repeat, 2))

fig = plt.figure(figsize=(12,4))
ax_a, ax_b = fig.subplots(1, 2, sharex=True, sharey=True)

# now simulate training the model many times, on different training data every time
# and evaluate using the test data
for i in tqdm(range(n_repeat), total=n_repeat, desc="Simulation iteration"):

    # train both models on newly generated training data
    X, y = make_blobs(n_samples=n_test, centers=cluster_centers,
                      cluster_std=sigma)
```

```

clf_a = SVC(kernel='linear', C=0.01).fit(X, y)
clf_b = SVC(kernel='linear', C=100.0).fit(X, y)

y_predict[:, i, 0] = clf_a.predict(x_test)
y_predict[:, i, 1] = clf_b.predict(x_test)

xx, yy = np.meshgrid(np.arange(-5, 5, .05),
                     np.arange(-5, 5, .05))

Z = clf_a.decision_function(np.c_[xx.ravel(), yy.ravel()])
Z_sim[:, i, 0] = Z
Z = Z.reshape(xx.shape)
ax_a.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');

plt.xlim(-5,5);
plt.ylim(-2,5);

Z = clf_b.decision_function(np.c_[xx.ravel(), yy.ravel()])
Z_sim[:, i, 1] = Z
Z = Z.reshape(xx.shape)
ax_b.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');

plt.xlim(-5,5);
plt.ylim(-2,5);

cs_a = ax_a.contour(xx, yy, Z_sim[:, :, 0].mean(axis=1).reshape(200,200), levels=[0.5],
                  colors='magenta', linewidths=2);
cs_b = ax_b.contour(xx, yy, Z_sim[:, :, 1].mean(axis=1).reshape(200,200), levels=[0.5],
                  colors='magenta', linewidths=2);

# plot data
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test, ax=ax_a, legend=False);
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test, ax=ax_b, legend=False);

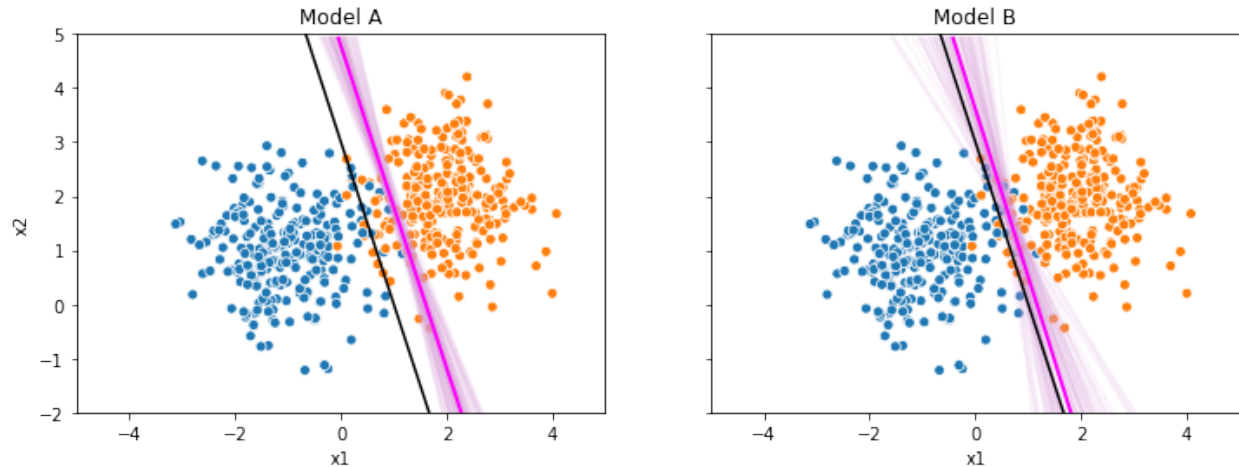
sns.lineplot(x=x_true, y=y_true, color='black', ax=ax_a)
sns.lineplot(x=x_true, y=y_true, color='black', ax=ax_b)

ax_a.set_title("Model A");
ax_b.set_title("Model B");

ax_a.set_ylabel("x2");
ax_a.set_xlabel("x1");
ax_b.set_xlabel("x1");

```

```
Simulation iteration:      100%|| 100/100 [00:05<00:00, 19.04it/s]
```



Kernels

```
def generate_polynomial_classifier_data(n=100, xrange=[-1,1], coefs=[1,0.5,0,2], sigma=0.5):
    x = np.random.uniform(xrange[0], xrange[1], size=(n, 2))
    ysep = np.polynomial.polynomial.polyval(x[:,0],coefs)
    y = (x[:,1]>ysep).astype(int)
    x[:,0] = x[:,0] + sigma * np.random.randn(n)
    x[:,1] = x[:,1] + sigma * np.random.randn(n)
    return x, y
```

```
n_repeat = 100
n_test = 500
n_train = 1000
sigma= 0.3
coefs=np.array([0.3, 1, -1.5, -2])
xrange=[-1,1]
```

```
y_predict = np.zeros((n_test, n_repeat, 2))
```

```
# generate test data once
x_test, y_test = generate_polynomial_classifier_data(n=n_test, xrange=xrange, coefs=coefs,
    sigma=sigma)
```

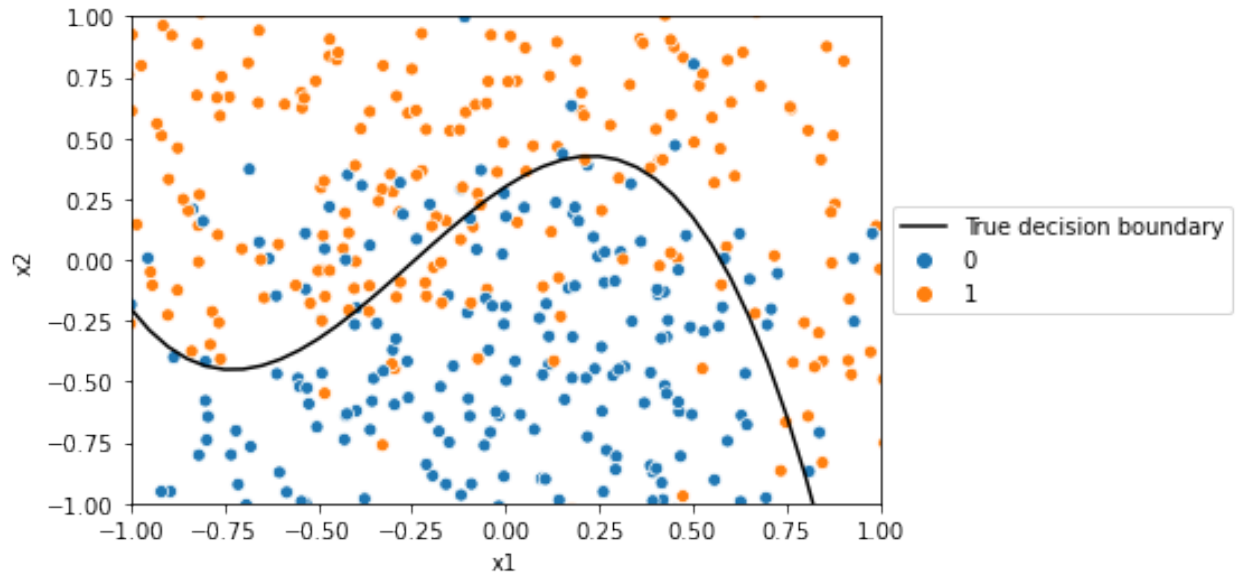
```
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test);
```

```
plt.xlabel("x1");
plt.ylabel("x2");
plt.xlim((xrange[0], xrange[1]));
plt.ylim((xrange[0], xrange[1]));
```

```
# Plot true function
```

```
xtrue = np.arange(-1.5, 1.5, .05)
ytrue = np.polynomial.polynomial.polyval(xtrue,coefs)
sns.lineplot(x=xtrue, y=ytrue, color='black', label='True decision boundary');
```

```
plt.legend(loc='center left', bbox_to_anchor=(1, 0.5), ncol=1);
```



Suppose we want to train a model to classify data that is separated by a polynomial boundary. Which will have greater bias, and which will have greater variance?

- **Model A:** SVM with linear kernel, $C = 1$
- **Model B:** SVM with RBF kernel, $C = 1$

```
Z_sim = np.zeros((3600, n_repeat, 2))

fig = plt.figure(figsize=(12,4))
ax_a, ax_b = fig.subplots(1, 2, sharex=True, sharey=True)

# now simulate training the model many times, on different training data every time
# and evaluate using the test data
for i in tqdm(range(n_repeat), total=n_repeat, desc="Simulation iteration"):

    # train both models on newly generated training data
    X, y = generate_polynomial_classifier_data(n=n_train, xrange=xrange, coefs=coefs,
        sigma=sigma)

    clf_a = SVC(kernel='linear', C=1).fit(X, y)
    clf_b = SVC(kernel='rbf', gamma=10, C=1).fit(X, y)

    y_predict[:, i, 0] = clf_a.predict(x_test)
    y_predict[:, i, 1] = clf_b.predict(x_test)

    xx, yy = np.meshgrid(np.arange(-1.5, 1.5, .05),
        np.arange(-1.5, 1.5, .05))

    Z = clf_a.decision_function(np.c_[xx.ravel(), yy.ravel()])
    Z_sim[:, i, 0] = Z
    Z = Z.reshape(xx.shape)
    ax_a.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');
    plt.xlim((xrange[0], xrange[1]));
    plt.ylim((xrange[0], xrange[1]));
```

```

Z = clf_b.decision_function(np.c_[xx.ravel(), yy.ravel()])
Z_sim[:, i, 1] = Z
Z = Z.reshape(xx.shape)
ax_b.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');
plt.xlim((xrange[0], xrange[1]));
plt.ylim((xrange[0], xrange[1]));

cs_a = ax_a.contour(xx, yy, Z_sim[:, :, 0].mean(axis=1).reshape(60,60), levels=[0.5],
    colors='magenta', linewidths=2);
cs_b = ax_b.contour(xx, yy, Z_sim[:, :, 1].mean(axis=1).reshape(60,60), levels=[0.5],
    colors='magenta', linewidths=2);

# Plot true function
xtrue = np.arange(-1.5, 1.5, .05)
ytrue = np.polynomial.polynomial.polyval(xtrue,coefs)
sns.lineplot(x=xtrue, y=ytrue, color='black', ax=ax_a);
sns.lineplot(x=xtrue, y=ytrue, color='black', ax=ax_b);

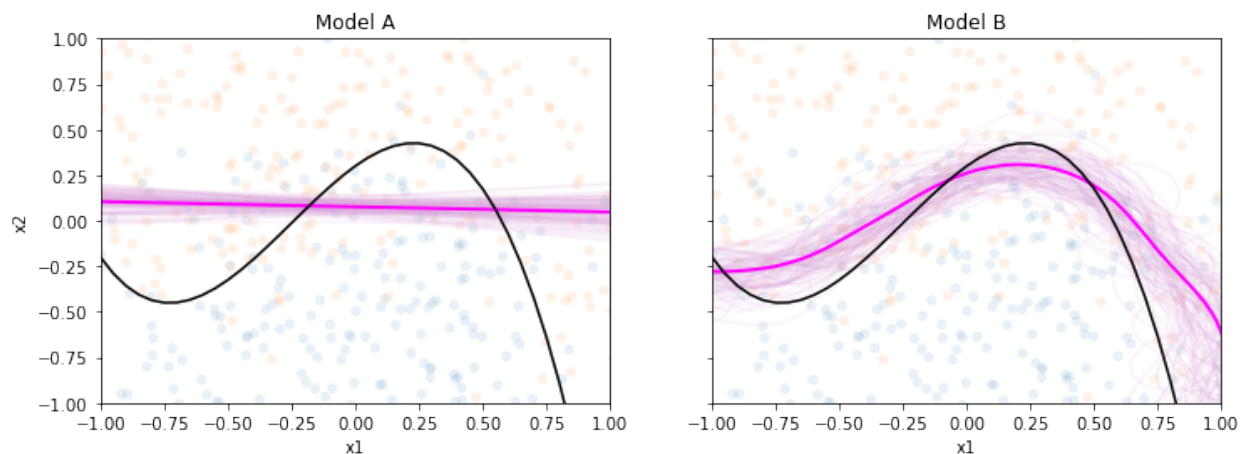
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test, ax=ax_a, legend=False, alpha=0.1);
sns.scatterplot(x=x_test[:,0], y=x_test[:,1], hue=y_test, ax=ax_b, legend=False, alpha=0.1);

ax_a.set_title("Model A");
ax_b.set_title("Model B");

ax_a.set_ylabel("x2");
ax_a.set_xlabel("x1");
ax_b.set_xlabel("x1");

```

Simulation iteration: 100%|| 100/100 [00:06<00:00, 14.70it/s]



RBF parameter

Recall that the RBF kernel is defined as

$$K(x, z) = \exp\left(-\frac{\|x - z\|_2^2}{\sigma^2}\right)$$

where σ is the bandwidth, or equivalently, using a γ parameter,

$$K(x, z) = \exp(-\gamma\|x - z\|_2^2)$$

For example, here is the RBF kernel centered on a single point, computed over the entire feature space, with two different values of γ :

```
from sklearn.metrics.pairwise import rbf_kernel

test_point = np.random.uniform(0,1,size=2)
xx, yy = np.meshgrid(np.arange(0, 5, .05), np.arange(0, 5, .05))

gamma_a=0.05
gamma_b=5
Z_a = rbf_kernel(np.c_[xx.ravel(), yy.ravel()], test_point.reshape(1, -1), gamma=gamma_a)
Z_b = rbf_kernel(np.c_[xx.ravel(), yy.ravel()], test_point.reshape(1, -1), gamma=gamma_b)

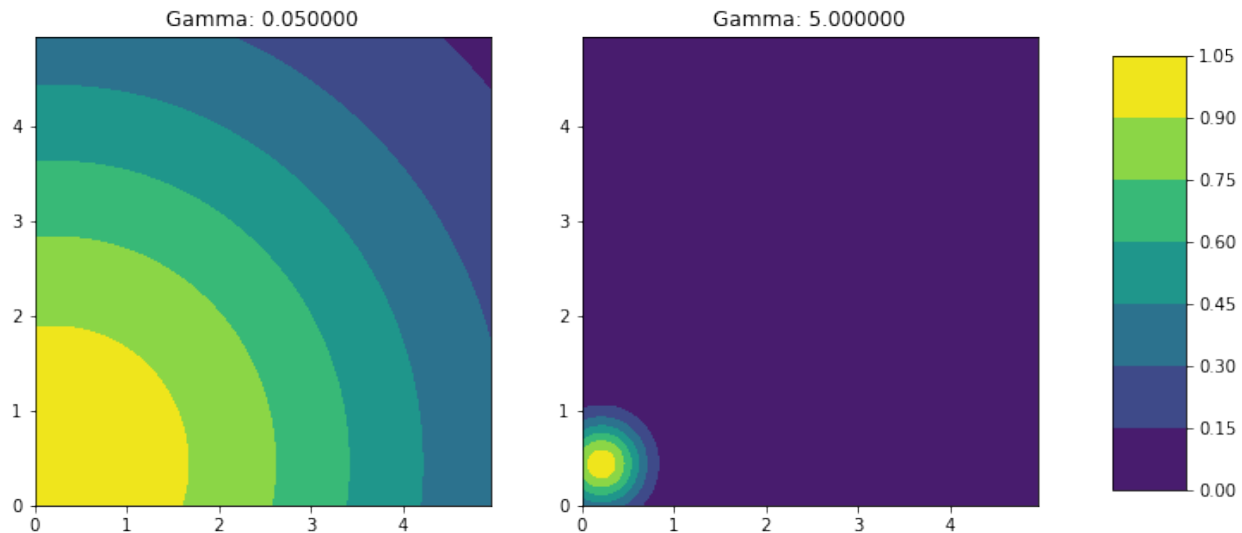
plt.figure(figsize=(12,5))
plt.subplot(1,2,1)

plt.scatter(x=test_point[0], y=test_point[1])
cs = plt.contourf(xx, yy, Z_a.reshape(xx.shape), vmin=0, vmax=1);
plt.title("Gamma: %f" % gamma_a);

plt.subplot(1,2,2)

plt.scatter(x=test_point[0], y=test_point[1])
cs = plt.contourf(xx, yy, Z_b.reshape(xx.shape), vmin=0, vmax=1);
plt.title("Gamma: %f" % gamma_b);

plt.subplots_adjust(right=0.8);
cbar_ax = plt.axes([0.85, 0.15, 0.05, 0.7]);
plt.colorbar(cax=cbar_ax);
```



We can see that when the kernel bandwidth is large (γ is small), the influence of each point extends much farther in the feature space than if the kernel bandwidth is small (γ is large).

Suppose we want to train a model to classify data that is separated by a polynomial boundary.

Which will have greater bias, and which will have greater variance?

- **Model A:** SVM with RBF kernel and $\gamma = 0.05$
- **Model B:** SVM with RBF kernel and $\gamma = 5$

```
n_repeat = 100
n_test = 500
n_train = 100
sigma = 0.3
coefs = np.array([0.3, 1, -1.5, -2])
xrange = [-1, 1]

y_predict = np.zeros((n_test, n_repeat, 2))

# generate test data once
x_test, y_test = generate_polynomial_classifier_data(n=n_test, xrange=xrange, coefs=coefs,
    sigma=sigma)

Z_sim = np.zeros((3600, n_repeat, 2))

fig = plt.figure(figsize=(12,4))
ax_a, ax_b = fig.subplots(1, 2, sharex=True, sharey=True)

# now simulate training the model many times, on different training data every time
# and evaluate using the test data
for i in tqdm(range(n_repeat), total=n_repeat, desc="Simulation iteration"):

    # train both models on newly generated training data
    X, y = generate_polynomial_classifier_data(n=n_train, xrange=xrange, coefs=coefs,
        sigma=sigma)

    clf_a = SVC(kernel='rbf', gamma=0.05, C=10).fit(X, y)
```



```

clf_b = SVC(kernel='rbf', gamma=5, C=10).fit(X, y)

y_predict[:, i, 0] = clf_a.predict(x_test)
y_predict[:, i, 1] = clf_b.predict(x_test)

xx, yy = np.meshgrid(np.arange(-1.5, 1.5, .05),
                     np.arange(-1.5, 1.5, .05))

Z = clf_a.decision_function(np.c_[xx.ravel(), yy.ravel()])
Z_sim[:, i, 0] = Z
Z = Z.reshape(xx.shape)
ax_a.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');
plt.xlim((xrange[0], xrange[1]));
plt.ylim((xrange[0], xrange[1]));

Z = clf_b.decision_function(np.c_[xx.ravel(), yy.ravel()])
Z_sim[:, i, 1] = Z
Z = Z.reshape(xx.shape)
ax_b.contour(xx, yy, Z, levels=[0.5], alpha=0.1, colors='plum');
plt.xlim((xrange[0], xrange[1]));
plt.ylim((xrange[0], xrange[1]));

cs_a = ax_a.contour(xx, yy, Z_sim[:, :, 0].mean(axis=1).reshape(60,60), levels=[0.5],
                  colors='magenta', linewidths=2);
cs_b = ax_b.contour(xx, yy, Z_sim[:, :, 1].mean(axis=1).reshape(60,60), levels=[0.5],
                  colors='magenta', linewidths=2);

# Plot true function
xtrue = np.arange(-1.5, 1.5, .05)
ytrue = np.polynomial.polynomial.polyval(xtrue,coefs)
sns.lineplot(x=xtrue, y=ytrue, color='black', ax=ax_a);
sns.lineplot(x=xtrue, y=ytrue, color='black', ax=ax_b);

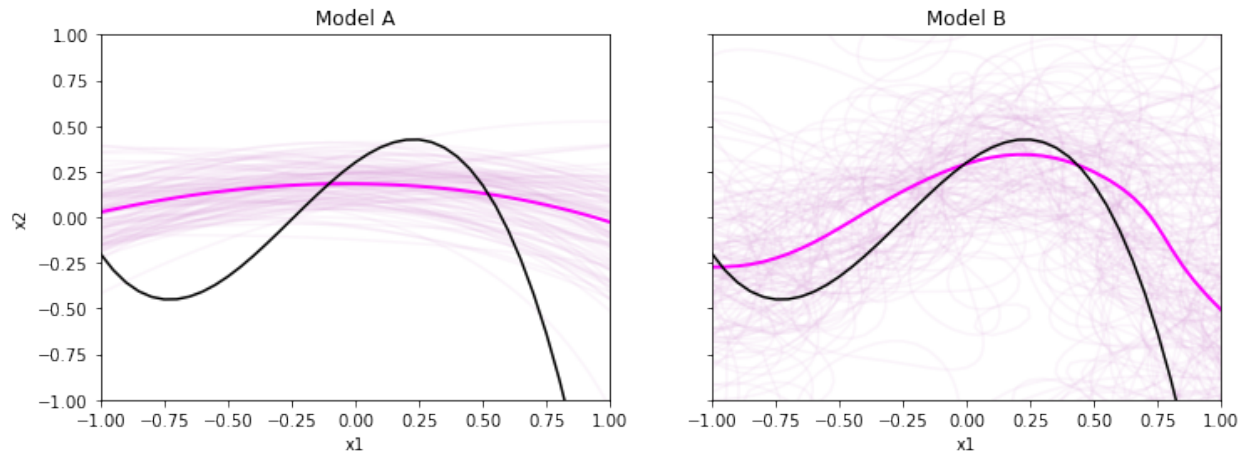
#sns.scatterplot(x_test[:,0], x_test[:,1], y_test, ax=ax_a, legend=False, alpha=0.1);
#sns.scatterplot(x_test[:,0], x_test[:,1], y_test, ax=ax_b, legend=False, alpha=0.1);

ax_a.set_title("Model A");
ax_b.set_title("Model B");

ax_a.set_ylabel("x2");
ax_a.set_xlabel("x1");
ax_b.set_xlabel("x1");

```

```
Simulation iteration:      100%|| 100/100 [00:01<00:00, 80.48it/s]
```



Hyperparameter search

For models with a single hyperparameter controlling bias-variance (for example: k in k nearest neighbors), we used `sklearn`'s `KFoldCV` or `validation_curve` to test a range of values for the hyperparameter, and to select the best one.

When we have *multiple* hyperparameters to tune, we can use `GridSearchCV` to select the best *combination* of them.

For example, we just saw three ways to tune the bias-variance of an SVM classifier:

- Changing the kernel
- Changing C
- For an RBF kernel, changing γ

To get the best performance from an SVM classifier, we need to find the best *combination* of these hyperparameters. This notebook shows how to use `GridSearchCV` to tune an SVM classifier.

We will work with a subset of the MNIST handwritten digits data. First, we will get the data, and assign a small subset of samples to training and test sets.

```
from sklearn.datasets import fetch_openml
X, y = fetch_openml('mnist_784', version=1, return_X_y=True)
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y, train_size=1000, test_size=300)
```

Let's try this initial parameter "grid":

```
param_grid = [
    {'C': [0.1, 1000], 'kernel': ['linear']},
    {'C': [0.1, 1000], 'gamma': [0.01, 0.0001], 'kernel': ['rbf']},
]
param_grid
```

```
[{'C': [0.1, 1000], 'kernel': ['linear']},
 {'C': [0.1, 1000], 'gamma': [0.01, 0.0001], 'kernel': ['rbf']}]
```

Now we'll set up the grid search. We can use `fit` on it, just like any other `sklearn` model.

I added `return_train_score=True` to my `GridSearchSV` so that it will show me training scores as well:


```

Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 1 tasks | elapsed: 1.6s
[Parallel(n_jobs=-1)]: Done 2 tasks | elapsed: 1.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 3 tasks | elapsed: 1.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 4 out of 18 | elapsed: 1.6s remaining: 5.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7669476681/5494-140268854393680-6278d26808724ef2a1143be09e7b5933.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 5 out of 18 | elapsed: 1.7s remaining: 4.3s
[Parallel(n_jobs=-1)]: Done 6 out of 18 | elapsed: 1.7s remaining: 3.5s
[Parallel(n_jobs=-1)]: Done 7 out of 18 | elapsed: 3.0s remaining: 4.6s
[Parallel(n_jobs=-1)]: Done 8 out of 18 | elapsed: 3.1s remaining: 3.9s
[Parallel(n_jobs=-1)]: Done 9 out of 18 | elapsed: 3.5s remaining: 3.5s
[Parallel(n_jobs=-1)]: Done 10 out of 18 | elapsed: 3.7s remaining: 3.0s
[Parallel(n_jobs=-1)]: Done 11 out of 18 | elapsed: 3.8s remaining: 2.4s

```

```

[Parallel(n_jobs=-1)]: Done 12 out of 18 | elapsed: 3.8s remaining: 1.9s
[Parallel(n_jobs=-1)]: Done 13 out of 18 | elapsed: 3.9s remaining: 1.5s
[Parallel(n_jobs=-1)]: Done 14 out of 18 | elapsed: 4.2s remaining: 1.2s
[Parallel(n_jobs=-1)]: Done 15 out of 18 | elapsed: 4.9s remaining: 1.0s
[Parallel(n_jobs=-1)]: Done 16 out of 18 | elapsed: 5.3s remaining: 0.7s
[Parallel(n_jobs=-1)]: Done 18 out of 18 | elapsed: 5.5s remaining: 0.0s
[Parallel(n_jobs=-1)]: Done 18 out of 18 | elapsed: 5.5s finished
CPU times: user 543 ms, sys: 52.6 ms, total: 596 ms
Wall time: 6.01 s

```

```

GridSearchCV(cv=3, error_score=nan,
             estimator=SVC(C=1.0, break_ties=False, cache_size=200,
                           class_weight=None, coef0=0.0,
                           decision_function_shape='ovr', degree=3,
                           gamma='scale', kernel='rbf', max_iter=-1,
                           probability=False, random_state=None, shrinking=True,
                           tol=0.001, verbose=False),
             iid='deprecated', n_jobs=-1,
             param_grid=[{'C': [0.1, 1000], 'kernel': ['linear']}],
                       {'C': [0.1, 1000], 'gamma': [0.01, 0.0001],
                        'kernel': ['rbf']}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
             scoring=None, verbose=100)

```

Here are the results:

```
pd.DataFrame(clf.cv_results_)
```

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_C \
0	0.339250	0.001733	0.163930	0.003930	0.1
1	0.321831	0.017181	0.166462	0.005801	1000
2	1.021387	0.013366	0.277623	0.010950	0.1
3	1.206247	0.037327	0.344387	0.018244	0.1
4	1.177458	0.072884	0.370081	0.135251	1000
5	1.112833	0.143619	0.274454	0.008783	1000

	param_kernel	param_gamma	params \
0	linear	NaN	{'C': 0.1, 'kernel': 'linear'}
1	linear	NaN	{'C': 1000, 'kernel': 'linear'}
2	rbf	0.01	{'C': 0.1, 'gamma': 0.01, 'kernel': 'rbf'}
3	rbf	0.0001	{'C': 0.1, 'gamma': 0.0001, 'kernel': 'rbf'}
4	rbf	0.01	{'C': 1000, 'gamma': 0.01, 'kernel': 'rbf'}
5	rbf	0.0001	{'C': 1000, 'gamma': 0.0001, 'kernel': 'rbf'}

	split0_test_score	split1_test_score	split2_test_score	mean_test_score \
0	0.892216	0.891892	0.879880	0.887996
1	0.892216	0.891892	0.879880	0.887996
2	0.116766	0.117117	0.117117	0.117000
3	0.116766	0.117117	0.117117	0.117000
4	0.116766	0.117117	0.117117	0.117000
5	0.116766	0.117117	0.117117	0.117000

	std_test_score	rank_test_score	split0_train_score	split1_train_score \
0	0.005740	1	1.000000	1.000000

1	0.005740	1	1.000000	1.000000
2	0.000165	3	0.117117	0.116942
3	0.000165	3	0.117117	0.116942
4	0.000165	3	1.000000	1.000000
5	0.000165	3	1.000000	1.000000

	split2_train_score	mean_train_score	std_train_score
0	1.000000	1.000	0.000000
1	1.000000	1.000	0.000000
2	0.116942	0.117	0.000083
3	0.116942	0.117	0.000083
4	1.000000	1.000	0.000000
5	1.000000	1.000	0.000000

To inform our search, we will use our understanding of how SVMs work, and especially how the C and γ parameters control the bias and variance of the SVM.

Linear kernel

Let's tackle the linear SVM first, since it's faster to fit. We didn't see any change in the accuracy when we vary C . So, we should extend the range of C over which we search.

I'll try higher and lower values of C , to see what happens.

```
param_grid = [
    {'C': [1e-6, 1e-4, 1e-2, 1e2, 1e4, 1e6], 'kernel': ['linear']},
]
param_grid
```

```
[{'C': [1e-06, 0.0001, 0.01, 100.0, 10000.0, 1000000.0], 'kernel': ['linear']}]
```

```
clf = GridSearchCV(SVC(), param_grid, cv=3, refit=True, verbose=100, n_jobs=-1,
    return_train_score=True)
%time clf.fit(X_train, y_train)
```

```
Fitting 3 folds for each of 6 candidates, totalling 18 fits
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent workers.
Memmapping (shape=(1000, 784), dtype=float64) to new file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
```

```

Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done    1 tasks      | elapsed:    1.7s

```

```

[Parallel(n_jobs=-1)]: Done 2 tasks | elapsed: 1.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 3 tasks | elapsed: 1.8s
[Parallel(n_jobs=-1)]: Done 4 out of 18 | elapsed: 1.8s remaining: 6.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1485620249/5494-140268854351472-fcbedfc1410b40a8bbe8b4518765d2d7.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 5 out of 18 | elapsed: 1.9s remaining: 4.8s
[Parallel(n_jobs=-1)]: Done 6 out of 18 | elapsed: 1.9s remaining: 3.8s
[Parallel(n_jobs=-1)]: Done 7 out of 18 | elapsed: 2.0s remaining: 3.1s
[Parallel(n_jobs=-1)]: Done 8 out of 18 | elapsed: 2.1s remaining: 2.7s
[Parallel(n_jobs=-1)]: Done 9 out of 18 | elapsed: 2.6s remaining: 2.6s
[Parallel(n_jobs=-1)]: Done 10 out of 18 | elapsed: 2.6s remaining: 2.1s
[Parallel(n_jobs=-1)]: Done 11 out of 18 | elapsed: 2.7s remaining: 1.7s
[Parallel(n_jobs=-1)]: Done 12 out of 18 | elapsed: 2.7s remaining: 1.3s
[Parallel(n_jobs=-1)]: Done 13 out of 18 | elapsed: 2.7s remaining: 1.1s
[Parallel(n_jobs=-1)]: Done 14 out of 18 | elapsed: 2.8s remaining: 0.8s
[Parallel(n_jobs=-1)]: Done 15 out of 18 | elapsed: 2.8s remaining: 0.6s
[Parallel(n_jobs=-1)]: Done 16 out of 18 | elapsed: 2.9s remaining: 0.4s
[Parallel(n_jobs=-1)]: Done 18 out of 18 | elapsed: 3.3s remaining: 0.0s
[Parallel(n_jobs=-1)]: Done 18 out of 18 | elapsed: 3.3s finished
CPU times: user 533 ms, sys: 60.5 ms, total: 594 ms
Wall time: 3.97 s

```

```

GridSearchCV(cv=3, error_score=nan,
             estimator=SVC(C=1.0, break_ties=False, cache_size=200,
                           class_weight=None, coef0=0.0,
                           decision_function_shape='ovr', degree=3,
                           gamma='scale', kernel='rbf', max_iter=-1,
                           probability=False, random_state=None, shrinking=True,
                           tol=0.001, verbose=False),
             iid='deprecated', n_jobs=-1,
             param_grid=[{'C': [1e-06, 0.0001, 0.01, 100.0, 10000.0, 1000000.0],
                          'kernel': ['linear']}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
             scoring=None, verbose=100)

```



```
pd.DataFrame(clf.cv_results_)
```

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_C \
0	0.390102	0.018605	0.179874	0.006953	1e-06
1	0.343758	0.025490	0.166590	0.006991	0.0001
2	0.354282	0.022208	0.203740	0.038052	0.01
3	0.326441	0.011751	0.170827	0.007733	100
4	0.327613	0.012534	0.173680	0.012300	10000
5	0.292291	0.005029	0.157839	0.010803	1e+06

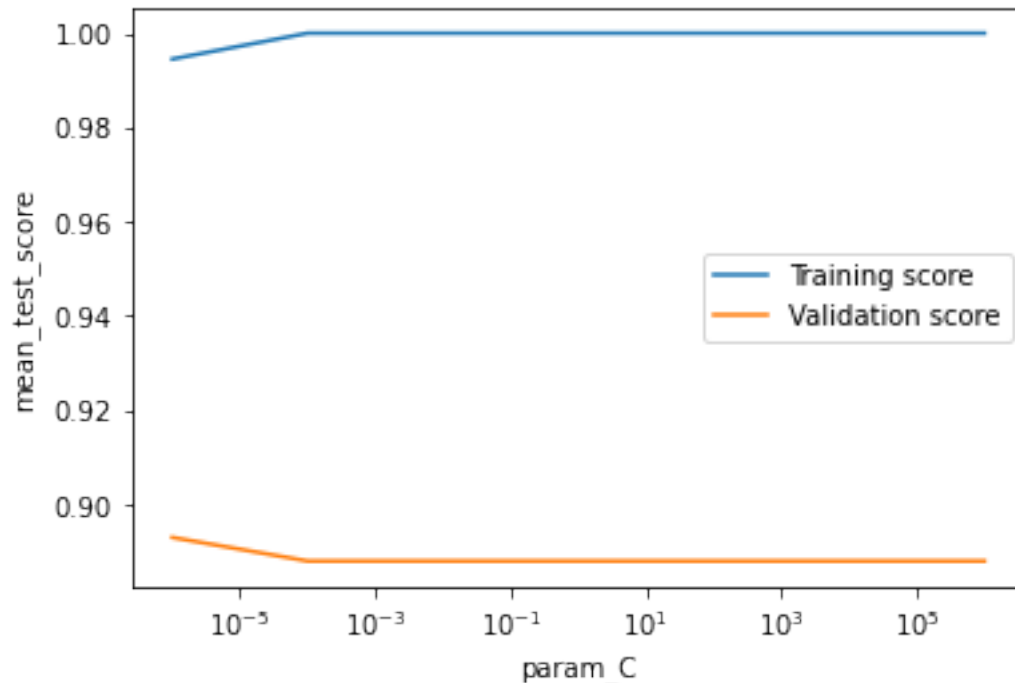
	param_kernel	params	split0_test_score \
0	linear	{'C': 1e-06, 'kernel': 'linear'}	0.892216
1	linear	{'C': 0.0001, 'kernel': 'linear'}	0.892216
2	linear	{'C': 0.01, 'kernel': 'linear'}	0.892216
3	linear	{'C': 100.0, 'kernel': 'linear'}	0.892216
4	linear	{'C': 10000.0, 'kernel': 'linear'}	0.892216
5	linear	{'C': 1000000.0, 'kernel': 'linear'}	0.892216

	split1_test_score	split2_test_score	mean_test_score	std_test_score \
0	0.894895	0.891892	0.893001	0.001346
1	0.891892	0.879880	0.887996	0.005740
2	0.891892	0.879880	0.887996	0.005740
3	0.891892	0.879880	0.887996	0.005740
4	0.891892	0.879880	0.887996	0.005740
5	0.891892	0.879880	0.887996	0.005740

	rank_test_score	split0_train_score	split1_train_score \
0	1	0.995495	0.991004
1	2	1.000000	1.000000
2	2	1.000000	1.000000
3	2	1.000000	1.000000
4	2	1.000000	1.000000
5	2	1.000000	1.000000

	split2_train_score	mean_train_score	std_train_score
0	0.997001	0.9945	0.002547
1	1.000000	1.0000	0.000000
2	1.000000	1.0000	0.000000
3	1.000000	1.0000	0.000000
4	1.000000	1.0000	0.000000
5	1.000000	1.0000	0.000000

```
sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_C', y='mean_train_score',
              label="Training score");
sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_C', y='mean_test_score',
              label="Validation score");
plt.xscale('log');
```



It looks like we get a slightly better validation score near the smaller values for C ! What does this mean?

Let's try:

```
param_grid = [
    {'C': np.linspace(1e-5, 1e-7, num=10), 'kernel': ['linear']},
]
param_grid
```

```
[{'C': array([1.0e-05, 8.9e-06, 7.8e-06, 6.7e-06, 5.6e-06, 4.5e-06, 3.4e-06,
            2.3e-06, 1.2e-06, 1.0e-07]),
  'kernel': ['linear']}]
```

```
clf = GridSearchCV(SVC(), param_grid, cv=3, refit=True, verbose=100, n_jobs=-1,
    return_train_score=True)
%time clf.fit(X_train, y_train)
```

Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent workers.

Memmapping (shape=(1000, 784), dtype=float64) to new file

/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(666,), dtype=int64).

Pickling array (shape=(334,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p

```
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
```

```

/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 1 tasks | elapsed: 1.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 2 tasks | elapsed: 1.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 3 tasks | elapsed: 1.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 4 tasks | elapsed: 1.9s
[Parallel(n_jobs=-1)]: Done 5 tasks | elapsed: 1.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 6 tasks | elapsed: 2.0s
[Parallel(n_jobs=-1)]: Done 7 tasks | elapsed: 2.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 8 tasks | elapsed: 2.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 9 tasks | elapsed: 2.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file

```

```

/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 10 tasks      | elapsed:    2.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 11 tasks      | elapsed:    2.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 12 tasks      | elapsed:    3.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 13 tasks      | elapsed:    3.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 14 tasks      | elapsed:    3.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 15 tasks      | elapsed:    3.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 16 out of 30 | elapsed:    3.2s remaining:    2.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_1607458443/5494-140268803120816-58df0bf4ca6440ec85d20e4d941d522e.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 17 out of 30 | elapsed:    3.3s remaining:    2.5s
[Parallel(n_jobs=-1)]: Done 18 out of 30 | elapsed:    3.7s remaining:    2.5s
[Parallel(n_jobs=-1)]: Done 19 out of 30 | elapsed:    3.8s remaining:    2.2s
[Parallel(n_jobs=-1)]: Done 20 out of 30 | elapsed:    3.8s remaining:    1.9s
[Parallel(n_jobs=-1)]: Done 21 out of 30 | elapsed:    3.9s remaining:    1.7s
[Parallel(n_jobs=-1)]: Done 22 out of 30 | elapsed:    4.1s remaining:    1.5s
[Parallel(n_jobs=-1)]: Done 23 out of 30 | elapsed:    4.2s remaining:    1.3s
[Parallel(n_jobs=-1)]: Done 24 out of 30 | elapsed:    4.2s remaining:    1.1s

```

```

[Parallel(n_jobs=-1)]: Done 25 out of 30 | elapsed: 4.2s remaining: 0.8s
[Parallel(n_jobs=-1)]: Done 26 out of 30 | elapsed: 4.7s remaining: 0.7s
[Parallel(n_jobs=-1)]: Done 27 out of 30 | elapsed: 4.7s remaining: 0.5s
[Parallel(n_jobs=-1)]: Done 28 out of 30 | elapsed: 5.0s remaining: 0.4s
[Parallel(n_jobs=-1)]: Done 30 out of 30 | elapsed: 5.1s remaining: 0.0s
[Parallel(n_jobs=-1)]: Done 30 out of 30 | elapsed: 5.1s finished
CPU times: user 574 ms, sys: 55.7 ms, total: 630 ms
Wall time: 5.73 s

```

```

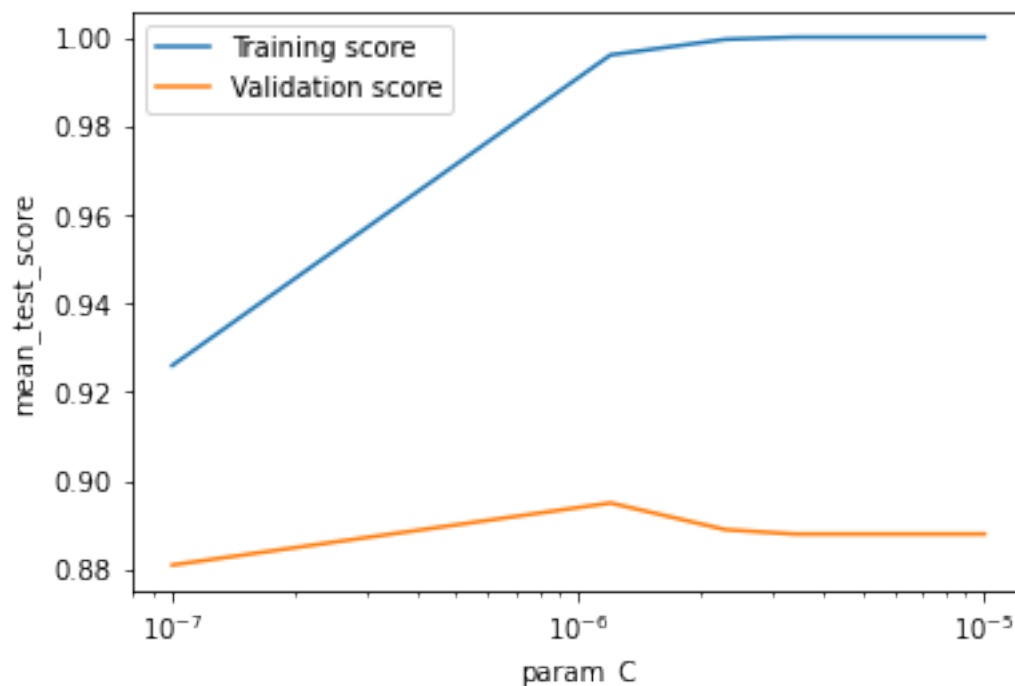
GridSearchCV(cv=3, error_score=nan,
             estimator=SVC(C=1.0, break_ties=False, cache_size=200,
                           class_weight=None, coef0=0.0,
                           decision_function_shape='ovr', degree=3,
                           gamma='scale', kernel='rbf', max_iter=-1,
                           probability=False, random_state=None, shrinking=True,
                           tol=0.001, verbose=False),
             iid='deprecated', n_jobs=-1,
             param_grid=[{'C': array([1.0e-05, 8.9e-06, 7.8e-06, 6.7e-06, 5.6e-06, 4.5e-06,
                                     3.4e-06,
                                     2.3e-06, 1.2e-06, 1.0e-07])},
                        {'kernel': ['linear']}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
             scoring=None, verbose=100)

```

```

sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_C', y='mean_train_score',
             label="Training score");
sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_C', y='mean_test_score',
             label="Validation score");
plt.xscale('log');

```



We can be satisfied that we have found a good hyperparameter only when we see the high bias AND high variance side of the validation curve!

RBF kernel

Now, let's look at the RBF kernel.

In our first search, the accuracy of the RBF kernel is very poor. We may have high bias, high variance, (or both).

When $C = 0.1$ in our first search, both training and validation scores were low. This suggests high bias.

When $C = 1000$ in our first search, training scores were high and validation scores were low. This suggests high variance.

What next? We know from our discussion of bias and variance of SVMs that to combat overfitting, we can decrease γ and/or decrease C .

For now, let's keep the higher value of C , and try to reduce the overfitting by decreasing γ .

```
param_grid = [
    {'C': [1000], 'gamma': [1e-4, 1e-5, 1e-6, 1e-7, 1e-8, 1e-9, 1e-10, 1e-11], 'kernel':
        ['rbf']},
]
param_grid
```

```
[{'C': [1000],
  'gamma': [0.0001, 1e-05, 1e-06, 1e-07, 1e-08, 1e-09, 1e-10, 1e-11],
  'kernel': ['rbf']}]
```

```
clf = GridSearchCV(SVC(), param_grid, cv=2, refit=True, verbose=100, n_jobs=-1,
    return_train_score=True)
%time clf.fit(X_train, y_train)
```

```
Fitting 2 folds for each of 8 candidates, totalling 16 fits
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent workers.
Memmapping (shape=(1000, 784), dtype=float64) to new file
    /dev/shm/joblib_memmapping_folder_5494_7591278100/5494-140268868998480-abc4746c813b489f9f724d9f00635e40.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
    /dev/shm/joblib_memmapping_folder_5494_7591278100/5494-140268868998480-abc4746c813b489f9f724d9f00635e40.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
    /dev/shm/joblib_memmapping_folder_5494_7591278100/5494-140268868998480-abc4746c813b489f9f724d9f00635e40.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
    /dev/shm/joblib_memmapping_folder_5494_7591278100/5494-140268868998480-abc4746c813b489f9f724d9f00635e40.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
```



```

Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 2 out of 16 | elapsed: 1.9s remaining: 13.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7591278100/5494-140268868998480-abc4746c813b489f9f724d9f00635e40.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(500,), dtype=int64).
Pickling array (shape=(500,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 3 out of 16 | elapsed: 2.1s remaining: 9.0s
[Parallel(n_jobs=-1)]: Done 4 out of 16 | elapsed: 2.2s remaining: 6.5s
[Parallel(n_jobs=-1)]: Done 5 out of 16 | elapsed: 2.2s remaining: 4.8s
[Parallel(n_jobs=-1)]: Done 6 out of 16 | elapsed: 2.2s remaining: 3.7s
[Parallel(n_jobs=-1)]: Done 7 out of 16 | elapsed: 2.4s remaining: 3.1s
[Parallel(n_jobs=-1)]: Done 8 out of 16 | elapsed: 2.5s remaining: 2.5s
[Parallel(n_jobs=-1)]: Done 9 out of 16 | elapsed: 2.5s remaining: 2.0s
[Parallel(n_jobs=-1)]: Done 10 out of 16 | elapsed: 2.7s remaining: 1.6s
[Parallel(n_jobs=-1)]: Done 11 out of 16 | elapsed: 2.8s remaining: 1.3s
[Parallel(n_jobs=-1)]: Done 12 out of 16 | elapsed: 2.9s remaining: 1.0s
[Parallel(n_jobs=-1)]: Done 13 out of 16 | elapsed: 3.0s remaining: 0.7s
[Parallel(n_jobs=-1)]: Done 14 out of 16 | elapsed: 3.0s remaining: 0.4s
[Parallel(n_jobs=-1)]: Done 16 out of 16 | elapsed: 3.6s remaining: 0.0s
[Parallel(n_jobs=-1)]: Done 16 out of 16 | elapsed: 3.6s finished
CPU times: user 699 ms, sys: 64.2 ms, total: 763 ms
Wall time: 4.35 s

```

```

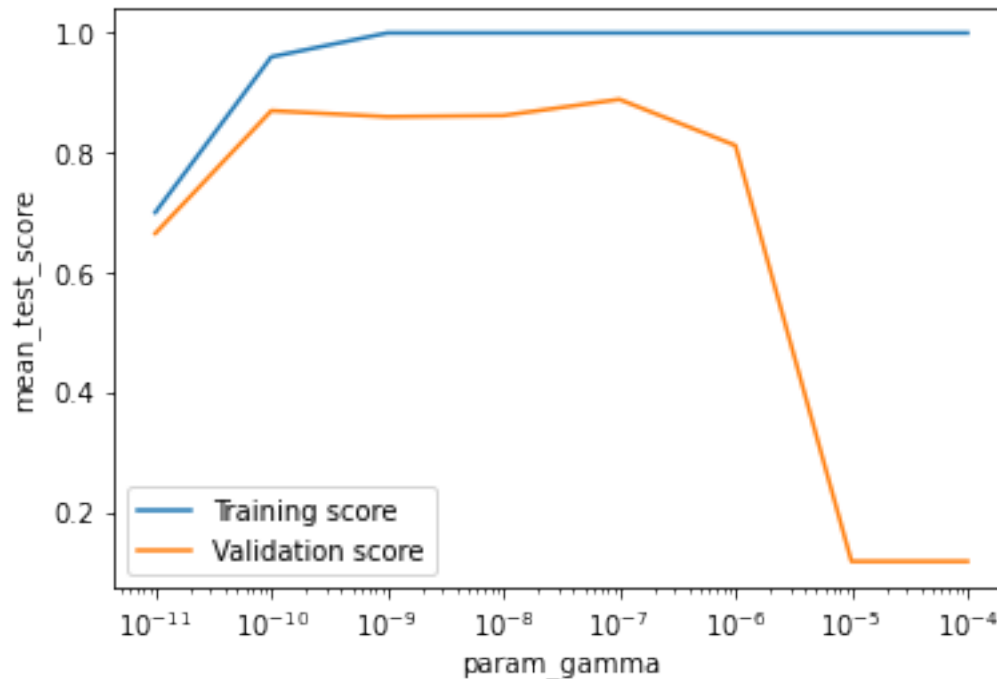
GridSearchCV(cv=2, error_score=nan,
             estimator=SVC(C=1.0, break_ties=False, cache_size=200,
                           class_weight=None, coef0=0.0,
                           decision_function_shape='ovr', degree=3,
                           gamma='scale', kernel='rbf', max_iter=-1,
                           probability=False, random_state=None, shrinking=True,
                           tol=0.001, verbose=False),
             iid='deprecated', n_jobs=-1,
             param_grid=[{'C': [1000],
                          'gamma': [0.0001, 1e-05, 1e-06, 1e-07, 1e-08, 1e-09,
                                    1e-10, 1e-11],
                          'kernel': ['rbf']}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
             scoring=None, verbose=100)

```

```

sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_gamma', y='mean_train_score',
             label="Training score")
sns.lineplot(data=pd.DataFrame(clf.cv_results_), x='param_gamma', y='mean_test_score',
             label="Validation score")
plt.xscale('log');

```



Here, we see that (at least for $C = 1000$), values of γ greater than $1e-5$ seem to overfit, while decreasing γ lower than $1e-10$ may underfit.

But we know that changing C also affects the bias variance tradeoff! For different values of C , the best value of γ will be different, and there may be a better *combination* of C and γ than any we have seen so far. We can try to increase and decrease C to see if that improves the validation score.

Now that we have a better idea of where to search, we can set up our “final” search grid.

We know that to find the best validation accuracy for the linear kernel, we should make sure our search space includes $1e-6$ and $1e-7$. I chose to vary C from $1e-8$ to $1e-4$. (I want to make sure the best value is not at the edge of the search space, so that we can be sure there isn't a better value if we go lower/higher.)

We know that to find the best validation accuracy for the RBF kernel, we should make sure our search space includes γ values around $1e-6$ and $1e-7$ when $C = 1000$. For larger values of C , we expect that we'll get better results with smaller values of γ . For smaller values of C , we expect that we'll get better results with larger values of γ . I chose to vary C from 1 to $1e6$ and γ from $1e-4$ to $1e-11$.

That's a big search grid, so this takes a long time to fit! (Try this at home with a larger training set to get an idea...)

```
param_grid = [
    {'C': [1e-8, 1e-7, 1e-6, 1e-5, 1e-4], 'kernel': ['linear']},
    {'C': [1, 1e2, 1e3, 1e4, 1e5, 1e6], 'gamma': [1e-4, 1e-5, 1e-6, 1e-7, 1e-8, 1e-9, 1e-10,
    1e-11], 'kernel': ['rbf']},
]
param_grid
```

```
[{'C': [1e-08, 1e-07, 1e-06, 1e-05, 0.0001], 'kernel': ['linear']},
 {'C': [1, 100.0, 1000.0, 10000.0, 100000.0, 1000000.0],
  'gamma': [0.0001, 1e-05, 1e-06, 1e-07, 1e-08, 1e-09, 1e-10, 1e-11],
  'kernel': ['rbf']}]
```

```

clf = GridSearchCV(SVC(), param_grid, cv=3, refit=True, verbose=100, n_jobs=-1,
    return_train_score=True)
clf.fit(X_train, y_train)

```

Fitting 3 folds for each of 53 candidates, totalling 159 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent workers.

Memmapping (shape=(1000, 784), dtype=float64) to new file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(666,), dtype=int64).

Pickling array (shape=(334,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(666,), dtype=int64).

Pickling array (shape=(334,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(666,), dtype=int64).

Pickling array (shape=(334,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

Pickling array (shape=(1000,), dtype=object).

Pickling array (shape=(667,), dtype=int64).

Pickling array (shape=(333,), dtype=int64).

Memmapping (shape=(1000, 784), dtype=float64) to old file

/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p

```

Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 1 tasks | elapsed: 1.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 2 tasks | elapsed: 1.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 3 tasks | elapsed: 1.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 4 tasks | elapsed: 2.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 5 tasks | elapsed: 2.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 6 tasks | elapsed: 2.5s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 7 tasks | elapsed: 2.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 8 tasks | elapsed: 2.7s
[Parallel(n_jobs=-1)]: Done 9 tasks | elapsed: 2.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 2.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 11 tasks | elapsed: 2.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 12 tasks | elapsed: 2.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 13 tasks | elapsed: 3.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 14 tasks | elapsed: 3.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 15 tasks | elapsed: 3.6s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 16 tasks      | elapsed:    4.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 17 tasks      | elapsed:    4.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 18 tasks      | elapsed:    4.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 19 tasks      | elapsed:    5.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 20 tasks      | elapsed:    5.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 21 tasks      | elapsed:    5.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 22 tasks      | elapsed:    5.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 23 tasks      | elapsed:    5.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 24 tasks      | elapsed:    6.1s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 25 tasks      | elapsed:    6.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 26 tasks      | elapsed:    6.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 27 tasks      | elapsed:    6.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 28 tasks      | elapsed:    6.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 29 tasks      | elapsed:    7.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 30 tasks      | elapsed:    7.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 31 tasks      | elapsed:    8.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 32 tasks      | elapsed:    8.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 33 tasks      | elapsed:    8.1s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 34 tasks      | elapsed:    8.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 35 tasks      | elapsed:    9.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 36 tasks      | elapsed:    9.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 37 tasks      | elapsed:    9.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 38 tasks      | elapsed:    9.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 39 tasks      | elapsed:    9.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 40 tasks      | elapsed:   10.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 41 tasks      | elapsed:   10.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 42 tasks      | elapsed:   10.6s

```



```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 43 tasks      | elapsed: 11.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 44 tasks      | elapsed: 11.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 45 tasks      | elapsed: 11.7s
[Parallel(n_jobs=-1)]: Done 46 tasks      | elapsed: 11.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 47 tasks      | elapsed: 11.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 48 tasks      | elapsed: 11.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 49 tasks      | elapsed: 12.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 50 tasks      | elapsed: 12.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 51 tasks      | elapsed: 12.2s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 52 tasks      | elapsed: 12.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 53 tasks      | elapsed: 12.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 54 tasks      | elapsed: 12.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 55 tasks      | elapsed: 12.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 56 tasks      | elapsed: 13.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 57 tasks      | elapsed: 13.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 58 tasks      | elapsed: 14.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 59 tasks      | elapsed: 14.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 60 tasks      | elapsed: 14.1s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 61 tasks      | elapsed: 14.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 62 tasks      | elapsed: 14.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 63 tasks      | elapsed: 14.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 64 tasks      | elapsed: 15.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 65 tasks      | elapsed: 15.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 66 tasks      | elapsed: 16.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 67 tasks      | elapsed: 16.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 68 tasks      | elapsed: 16.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 69 tasks      | elapsed: 16.7s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 70 tasks      | elapsed: 16.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 71 tasks      | elapsed: 17.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 72 tasks      | elapsed: 17.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 73 tasks      | elapsed: 17.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 74 tasks      | elapsed: 17.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 75 tasks      | elapsed: 17.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 76 tasks      | elapsed: 17.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 77 tasks      | elapsed: 17.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 78 tasks      | elapsed: 18.2s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 79 tasks      | elapsed: 18.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 80 tasks      | elapsed: 18.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 81 tasks      | elapsed: 18.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 82 tasks      | elapsed: 18.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 83 tasks      | elapsed: 18.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 84 tasks      | elapsed: 18.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 85 tasks      | elapsed: 19.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 86 tasks      | elapsed: 19.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 87 tasks      | elapsed: 20.2s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 88 tasks      | elapsed: 20.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 89 tasks      | elapsed: 20.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 90 tasks      | elapsed: 20.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 91 tasks      | elapsed: 20.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 92 tasks      | elapsed: 20.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 93 tasks      | elapsed: 21.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 94 tasks      | elapsed: 21.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 95 tasks      | elapsed: 21.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 96 tasks      | elapsed: 21.9s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 97 tasks      | elapsed: 21.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 98 tasks      | elapsed: 21.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 99 tasks      | elapsed: 22.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 100 tasks     | elapsed: 22.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 101 tasks     | elapsed: 22.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 102 tasks     | elapsed: 22.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 103 tasks     | elapsed: 22.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 104 tasks     | elapsed: 22.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 105 tasks     | elapsed: 22.9s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 106 tasks      | elapsed:   22.9s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 107 tasks      | elapsed:   23.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 108 tasks      | elapsed:   23.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 109 tasks      | elapsed:   23.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 110 tasks      | elapsed:   23.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 111 tasks      | elapsed:   23.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 112 tasks      | elapsed:   25.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 113 tasks      | elapsed:   25.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 114 tasks      | elapsed:   25.0s

```



```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 115 tasks      | elapsed:   25.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 116 tasks      | elapsed:   25.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 117 tasks      | elapsed:   25.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 118 tasks      | elapsed:   25.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 119 tasks      | elapsed:   26.1s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 120 tasks      | elapsed:   26.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 121 tasks      | elapsed:   26.3s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 122 tasks      | elapsed:   26.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 123 tasks      | elapsed:   26.5s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 124 tasks      | elapsed:   26.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 125 tasks      | elapsed:   27.2s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 126 tasks      | elapsed:   27.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 127 tasks      | elapsed:   27.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 128 tasks      | elapsed:   27.5s
[Parallel(n_jobs=-1)]: Done 129 tasks      | elapsed:   27.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 130 tasks      | elapsed:   27.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 131 tasks      | elapsed:   27.6s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 132 tasks      | elapsed:   27.7s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 133 tasks      | elapsed:   28.4s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 134 tasks      | elapsed:   28.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 135 tasks      | elapsed:   28.5s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 136 tasks      | elapsed:   29.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 137 tasks      | elapsed:   29.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 138 tasks      | elapsed:   29.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 139 tasks      | elapsed:   29.8s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 140 tasks      | elapsed:   30.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 141 tasks      | elapsed:   30.7s

```

```

Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 142 tasks      | elapsed:   30.7s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 143 tasks      | elapsed:   31.0s
[Parallel(n_jobs=-1)]: Done 144 tasks      | elapsed:   31.0s
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(666,), dtype=int64).
Pickling array (shape=(334,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
Memmapping (shape=(1000, 784), dtype=float64) to old file
/dev/shm/joblib_memmapping_folder_5494_7488309753/5494-140268803145936-f137eaa72d94493b95d0bdc6c1436493.p
Pickling array (shape=(1000,), dtype=object).
Pickling array (shape=(667,), dtype=int64).
Pickling array (shape=(333,), dtype=int64).
[Parallel(n_jobs=-1)]: Done 146 out of 159 | elapsed:   31.1s remaining:   2.8s
[Parallel(n_jobs=-1)]: Done 148 out of 159 | elapsed:   31.8s remaining:   2.4s
[Parallel(n_jobs=-1)]: Done 150 out of 159 | elapsed:   31.9s remaining:   1.9s
[Parallel(n_jobs=-1)]: Done 152 out of 159 | elapsed:   32.1s remaining:   1.5s
[Parallel(n_jobs=-1)]: Done 154 out of 159 | elapsed:   32.1s remaining:   1.0s
[Parallel(n_jobs=-1)]: Done 156 out of 159 | elapsed:   32.7s remaining:   0.6s
[Parallel(n_jobs=-1)]: Done 159 out of 159 | elapsed:   32.9s finished

```

```

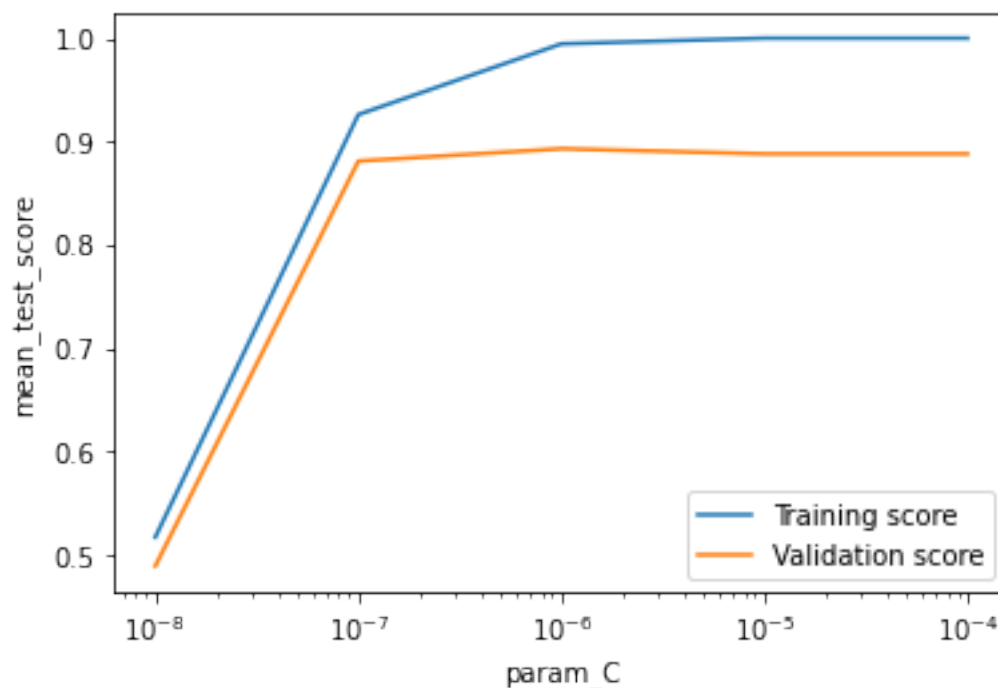
GridSearchCV(cv=3, error_score=nan,
             estimator=SVC(C=1.0, break_ties=False, cache_size=200,
                           class_weight=None, coef0=0.0,
                           decision_function_shape='ovr', degree=3,
                           gamma='scale', kernel='rbf', max_iter=-1,
                           probability=False, random_state=None, shrinking=True,
                           tol=0.001, verbose=False),
             iid='deprecated', n_jobs=-1,
             param_grid=[{'C': [1e-08, 1e-07, 1e-06, 1e-05, 0.0001],
                          'kernel': ['linear']},
                        {'C': [1, 100.0, 1000.0, 10000.0, 100000.0, 1000000.0],
                          'gamma': [0.0001, 1e-05, 1e-06, 1e-07, 1e-08, 1e-09,
                                     1e-10, 1e-11],
                          'kernel': ['rbf']}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=True,
             scoring=None, verbose=100)

```

For the linear kernel, here's what we found:

```
df_cv = pd.DataFrame(clf.cv_results_)
df_cv = df_cv[df_cv['param_kernel']=='linear']
```

```
sns.lineplot(data=df_cv, x='param_C', y='mean_train_score', label="Training score")
sns.lineplot(data=df_cv, x='param_C', y='mean_test_score', label="Validation score")
plt.xscale('log');
```



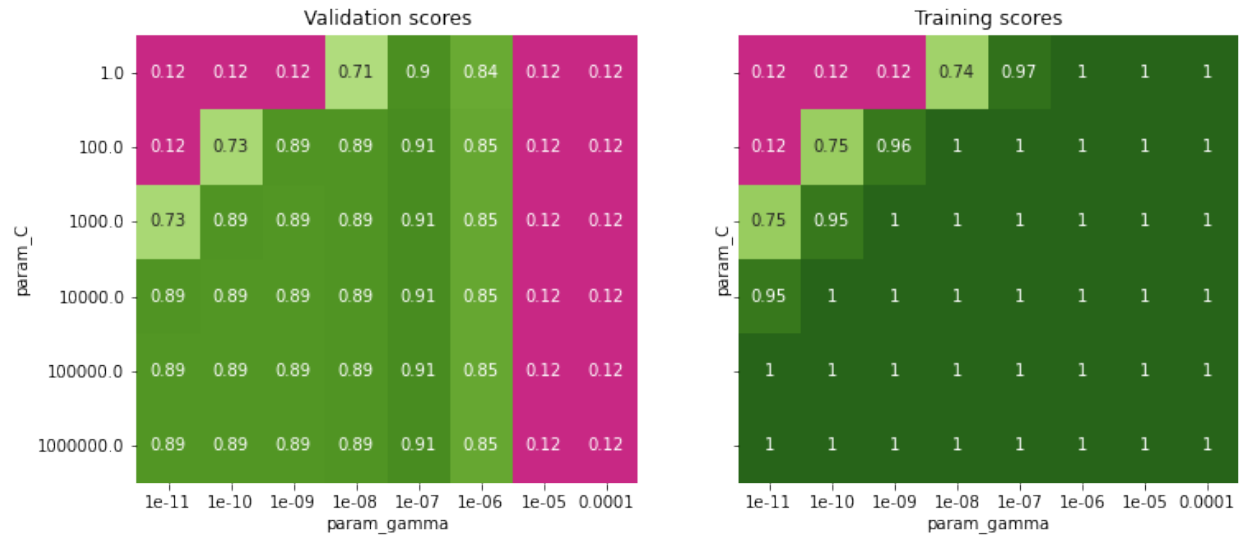
For the RBF kernel, here's what we found:

```
df_cv = pd.DataFrame(clf.cv_results_)
df_cv = df_cv[df_cv['param_kernel']=='rbf']

plt.figure(figsize=(12,5))

ax1=plt.subplot(1,2,1)
pvt = pd.pivot_table(df_cv, values='mean_test_score', index='param_C', columns='param_gamma')
sns.heatmap(pvt, annot=True, cbar=False, vmin=0, vmax=1, cmap='PiYG');
plt.title("Validation scores");

ax2=plt.subplot(1,2,2, sharey=ax1)
plt.setp(ax2.get_yticklabels(), visible=False)
pvt = pd.pivot_table(df_cv, values='mean_train_score', index='param_C',
    columns='param_gamma')
sns.heatmap(pvt, annot=True, cbar=False, vmin=0, vmax=1, cmap='PiYG');
plt.title("Training scores");
```



We see that γ and C control the bias-variance tradeoff of the SVM model as follows.

- In the top left region, C is small (the margin is wider) and γ is small (the kernel bandwidth is large). In this region, the model has more bias (is prone to underfit). The validation scores and training scores are both low.
- On the right side (and we'd expect to see this on the bottom right if we extend the range of C even higher), C is large (the margin is narrower) and γ is large (the kernel bandwidth is small). In this region, the model has more variance (is likely to overfit). The validation scores are low, but the training scores are high.

In the middle, we have a region of good combinations of C and γ .

Since the parameter grid above shows us the validation accuracy decreasing both as we increase each parameter* and also as we decrease each parameter, we can be a bit more confident that we captured the point in the bias-variance surface where the error is smallest.

* C is different because increasing C even more may not actually change the margin.

We can see the “best” parameters, with which the model was re-fitted:

```
print(clf.best_params_)
```

```
{'C': 100.0, 'gamma': 1e-07, 'kernel': 'rbf'}
```

And we can evaluate the re-fitted model on the test set. (Note that the GridSearchCV only used the training set; we have not used the test set at all for model fitting.)

```
y_pred = clf.predict(X_test)
```

```
accuracy_score(y_pred, y_test)
```

```
0.9033333333333333
```