Gaussian Naive Bayes

In Bayesian classification, we're interested in finding the probability of a label given some observed features, which we can write as $P(L \mid \text{features})$. Bayes's theorem tells us how to express this in terms of quantities we can compute more directly:

$$P(L \mid \text{features}) = \frac{P(\text{features} \mid L)P(L)}{P(\text{features})}$$

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
sns.set()
```

In [2]:
```
from sklearn.datasets import make_blobs
```

In [3]:
```
X, y = make_blobs(100, 2, centers=2, random_state=2, cluster_std=1.5)
```

In [4]:
```
X[0:5]
```

Out[4]:
```
array([[ 0.92141506, -9.98499137],
       [-5.26927614, -9.6186543 ],
       [-0.45292089, -6.04316334],
       [-0.0856312 , -2.16867404],
       [ 1.53194956, -0.36022153]])
```

In [5]:
```
y
```

Out[5]:
```
array([0, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 0, 0, 1,
       1, 0, 0, 0, 1, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1,
       1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 0,
       0, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0,
       1, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1])
```

In [6]:
```
plt.scatter(X[:, 0], X[:, 1], c=y, s=50, cmap='RdBu');
```

In [7]:
```
from sklearn.naive_bayes import GaussianNB
```

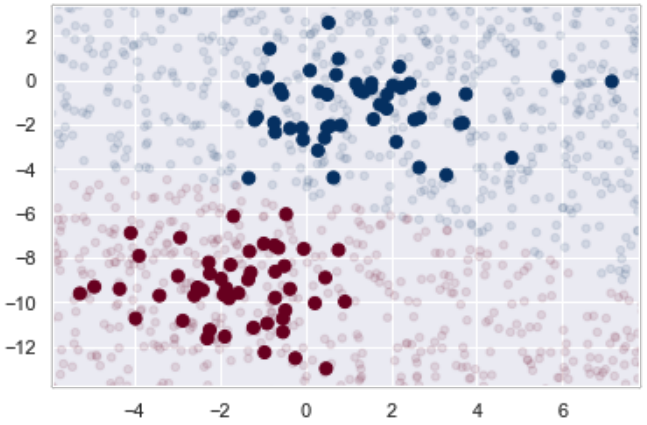
In [8]:
```
model = GaussianNB()
model.fit(X, y);
```

Now let's generate some new data and predict the label:

In [9]:
```
rng = np.random.RandomState(0)
Xnew = [-6, -14] + [14, 18] * rng.rand(1000, 2)
ynew = model.predict(Xnew)
```

In [10]:
```
plt.scatter(X[:, 0], X[:, 1], c=y, s=50, cmap='RdBu')
lim = plt.axis()

plt.scatter(Xnew[:, 0], Xnew[:, 1], c=ynew, s=20, cmap='RdBu', alpha=0.1)
plt.axis(lim);
```



In [11]:
```
yprob = model.predict_proba(Xnew)
yprob[-8:].round(2)
```

Out[11]:
```
array([[0.92, 0.08],
       [1.  , 0.  ],
       [0.  , 1.  ],
       [0.  , 1.  ],
       [0.  , 1.  ],
       [0.  , 1.  ],
       [0.  , 1.  ],
       [0.  , 1.  ]])
```

In [12]:
```
ynew[-8:]
```

Out[12]:
```
array([0, 0, 1, 1, 1, 1, 1, 1])
```

In [13]:
```
Xnew[-8:]
```

Out[13]:
```
array([[ 4.24702389, -7.83992604],
       [-0.74176013, -7.53608286],
       [ 2.63265821,  2.20738264],
       [-3.57529469,  1.75359298],
       [-5.61285581, -2.11390527],
       [-0.19785578,  0.24306794],
       [ 4.09677358, -5.35805947],
       [ 3.01409651, -4.96808365]])
```

Gaussian Naive Bayes - Iris dataset

In [14]:
```
from sklearn import datasets
from sklearn import metrics
from sklearn.naive_bayes import GaussianNB
```

In [15]:
```
# load the iris datasets
dataset = datasets.load_iris()
```

In [16]:
```
dataset.data[:5]
```

Out[16]:
```
array([[5.1, 3.5, 1.4, 0.2],
       [4.9, 3. , 1.4, 0.2],
       [4.7, 3.2, 1.3, 0.2],
       [4.6, 3.1, 1.5, 0.2],
       [5. , 3.6, 1.4, 0.2]])
```

In [17]:
```
dataset.target[:5]
```

Out[17]:
```
array([0, 0, 0, 0, 0])
```

In [18]:
```
# fit a Naive Bayes model to the data
model = GaussianNB()

model.fit(dataset.data, dataset.target)
print(model)
```

```
GaussianNB(priors=None, var_smoothing=1e-09)
```

In [19]:
```
# make predictions

expected = dataset.target
predicted = model.predict(dataset.data)
```

In [20]:
```
expected.shape
```

Out[20]: (150,)

In [21]:
```
print("Number of mislabeled points out of a total {} points : {}, performance {:05.2f}%"
      .format(
          expected.shape[0],
          (expected != predicted).sum(),
          100*(1-(expected != predicted).sum()/expected.shape[0])
))
```

```
Number of mislabeled points out of a total 150 points : 6, performance 96.00%
```

In [ ]:
```

```

In [22]:
```
print(metrics.confusion_matrix(expected, predicted))
```

```
[[50  0  0]
 [ 0 47  3]
 [ 0  3 47]]
```

In [23]:
```
probs = model.predict_proba(dataset.data).round(2)
```

In [24]:
```
probs[0:50,:]
```

Out[24]:
```
array([[1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
       [1., 0., 0.],
```

In [25]:
```
probs[50:100,:]
```

Out[25]:
```
array([[0.  , 0.8 , 0.2 ],
       [0.  , 0.95, 0.05],
       [0.  , 0.46, 0.54],
       [0.  , 1.  , 0.  ],
       [0.  , 0.95, 0.05],
       [0.  , 1.  , 0.  ],
       [0.  , 0.66, 0.34],
       [0.  , 1.  , 0.  ],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 0.98, 0.02],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 0.15, 0.85],
       [0.  , 1.  , 0.  ],
       [0.  , 0.93, 0.07],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 0.99, 0.01],
       [0.  , 0.91, 0.09],
       [0.  , 0.08, 0.92],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 0.61, 0.39],
       [0.  , 0.99, 0.01],
       [0.  , 0.88, 0.12],
       [0.  , 0.8 , 0.2 ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
       [0.  , 0.99, 0.01],
       [0.  , 1.  , 0.  ],
       [0.  , 1.  , 0.  ],
```

In [26]:
```
# Misclassified data for class 1

a = probs[50:100,:]
a[a[:,1] < a[:,2]]
```

Out[26]:
```
array([[0.  , 0.46, 0.54],
       [0.  , 0.15, 0.85],
       [0.  , 0.08, 0.92]])
```

In [27]:
```
dataset.data[np.add(50, np.where(a[:,1] < a[:,2]))]
```

Out[27]:
```
array([[[6.9, 3.1, 4.9, 1.5],
        [5.9, 3.2, 4.8, 1.8],
        [6.7, 3. , 5. , 1.7]]])
```

In [28]:
```
probs[100:150,:]
```

Out[28]:
```
array([[0.  , 0.  , 1.  ],
       [0.  , 0.03, 0.97],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.97, 0.03],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.01, 0.99],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.96, 0.04],
       [0.  , 0.  , 1.  ],
       [0.  , 0.01, 0.99],
       [0.  , 0.  , 1.  ],
       [0.  , 0.13, 0.87],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.2 , 0.8 ],
       [0.  , 0.11, 0.89],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.71, 0.29],
       [0.  , 0.49, 0.51],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.19, 0.81],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.  , 1.  ],
       [0.  , 0.03, 0.97],
       [0.  , 0.  , 1.  ],
```

In [29]:
```
# Misclassified data for class 2

a = probs[100:150,:]
a[a[:,2] < a[:,1]]
```

Out[29]:
```
array([[0.  , 0.97, 0.03],
       [0.  , 0.96, 0.04],
       [0.  , 0.71, 0.29]])
```

In [30]:
```
dataset.data[np.add(100, np.where(a[:,2] < a[:,1]))]
```

Out[30]:
```
array([[[4.9, 2.5, 4.5, 1.7],
        [6. , 2.2, 5. , 1.5],
        [6.3, 2.8, 5.1, 1.5]]])
```

In [ ]:
```

```