In [1]:

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

Importação de métodos de validação e medidas de desempenho

Métodos de validação

In [2]:

```
from sklearn.model_selection import train_test_split # Holdout
from sklearn.model_selection import StratifiedKFold # Cross-validation
```

Medidas de desempenho

In [3]:

```
from sklearn.metrics import confusion_matrix, plot_confusion_matrix, ConfusionMa
trixDisplay # Matriz de confusão
from sklearn.metrics import accuracy_score # Acurácia
```

Definições auxiliares

Funções para plot de linhas de decisão

In [4]:

```
def make_meshgrid(x, y, h=.02):
    x_min, x_max = x.min() - 1, x.max() + 1
    y_min, y_max = y.min() - 1, y.max() + 1
    xx, yy = np.meshgrid(np.arange(x_min, x_max, h), np.arange(y_min, y_max, h))
    return xx, yy

def plot_contours(ax, clf, xx, yy, **params):
    Z = clf.predict(np.c_[xx.ravel(), yy.ravel()])
    Z = Z.reshape(xx.shape)
    out = ax.contourf(xx, yy, Z, **params)
    return out

def plot_data_and_boudaries(clf, X, Y, row=1, column=1, index=1, title='', x_lab
el='', y_label=''):
    ax = plt.subplot(row, column, index)
    # Set-up grid for plotting.
    X0, X1 = X[:, 0], X[:, 1]
    xx, yy = make_meshgrid(X0, X1)

    plot_contours(ax, clf, xx, yy, cmap=plt.cm.coolwarm, alpha=0.8)
    ax.scatter(X0, X1, c=Y, cmap=plt.cm.coolwarm, s=20, edgecolors='k')
    ax.set_ylabel(y_label)
    ax.set_xlabel(x_label)
    ax.set_xticks(())
    ax.set_yticks(())
    ax.set_title(title)

    return ax
```

Dados1

In [5]:

```
dataset = pd.read_csv('../datasets/dados1.csv')
```

In [6]:

```
dataset.head()
```

Out[6]:

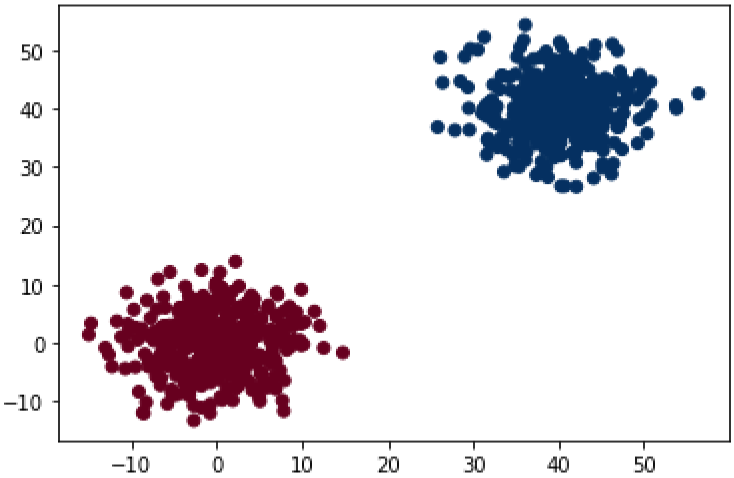
	V1	V2	V3
0	3.593917	-6.403765	1
1	1.879632	-9.968132	1
2	6.764671	-5.860354	1
3	-3.284518	-7.496510	1
4	2.412762	-6.015894	1

In [7]:

```
plt.scatter(dataset.V1, dataset.V2, c=dataset.V3, cmap='RdBu')
```

Out[7]:

```
<matplotlib.collections.PathCollection at 0x119f9d410>
```



In [8]:

```
X = dataset.values[:, :-1]
Y = dataset.values[:, -1]
```

MLP

In [9]:

```
from sklearn.neural_network import MLPClassifier
```

Holdout

In [10]:

```
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, stratify=Y, random_sta
te=42)
```

In [11]:

```
mlp = MLPClassifier(hidden_layer_sizes=(1), max_iter=5000, random_state=42)
mlp.fit(X_train, Y_train)
```

Out[11]:

```
MLPClassifier(activation='relu', alpha=0.0001, batch_size='auto', be
ta_1=0.9,
              beta_2=0.999, early_stopping=False, epsilon=1e-08,
              hidden_layer_sizes=1, learning_rate='constant',
              learning_rate_init=0.001, max_fun=15000, max_iter=500
0,
              momentum=0.9, n_iter_no_change=10, nesterovs_momentum=
True,
              power_t=0.5, random_state=42, shuffle=True, solver='ad
am',
              tol=0.0001, validation_fraction=0.1, verbose=False,
              warm_start=False)
```

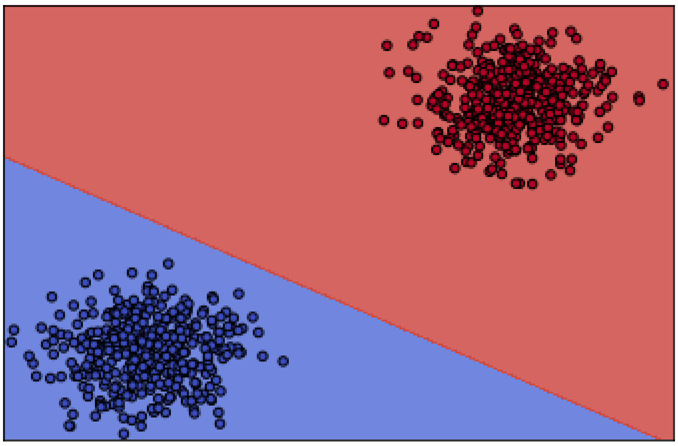
Linha de decisão

In [12]:

```
plot_data_and_boudaries(mlp, X, Y)
```

Out[12]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x11a0d7090>
```



Acurácia

In [13]:

```
accuracy_score(mlp.predict(X_test), Y_test)
```

Out[13]:

```
1.0
```

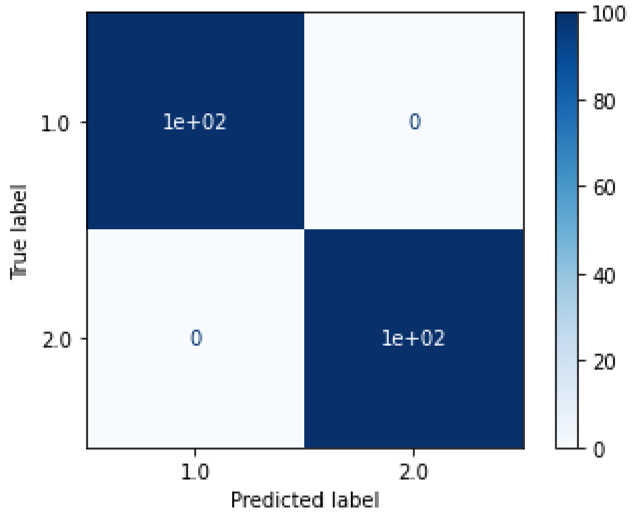
Matriz de confusão

In [14]:

```
plot_confusion_matrix(mlp, X_test, Y_test, cmap='Blues')
```

Out[14]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x
11a11eb50>
```



Cross-validation

In [15]:

```
skf = StratifiedKFold()
```

In [16]:

```
mlps = []

for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    mlp = MLPClassifier(hidden_layer_sizes=(1), max_iter=5000, random_state=42)
    mlp.fit(X_train, Y_train)
    mlps.append(mlp)
```

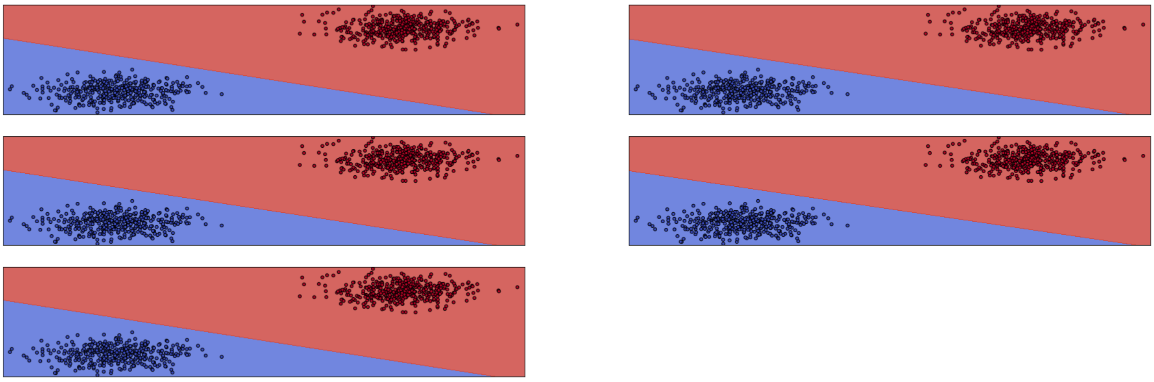
Linha de decisão

In [17]:

```
columns = 2
rows = (skf.get_n_splits() // columns) + 1
rows

plt.figure(figsize=(10 * rows, 10))

for i in range(skf.get_n_splits()):
    plot_data_and_boudaries(mlps[i], X, Y, rows, columns, i+1)
```



Acurácia

In [18]:

```
scores = []

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    score = accuracy_score(mlps[i].predict(X_test), Y_test)
    scores.append(score)
    i += 1

scores
```

Out[18]:

```
[1.0, 1.0, 1.0, 1.0, 1.0]
```

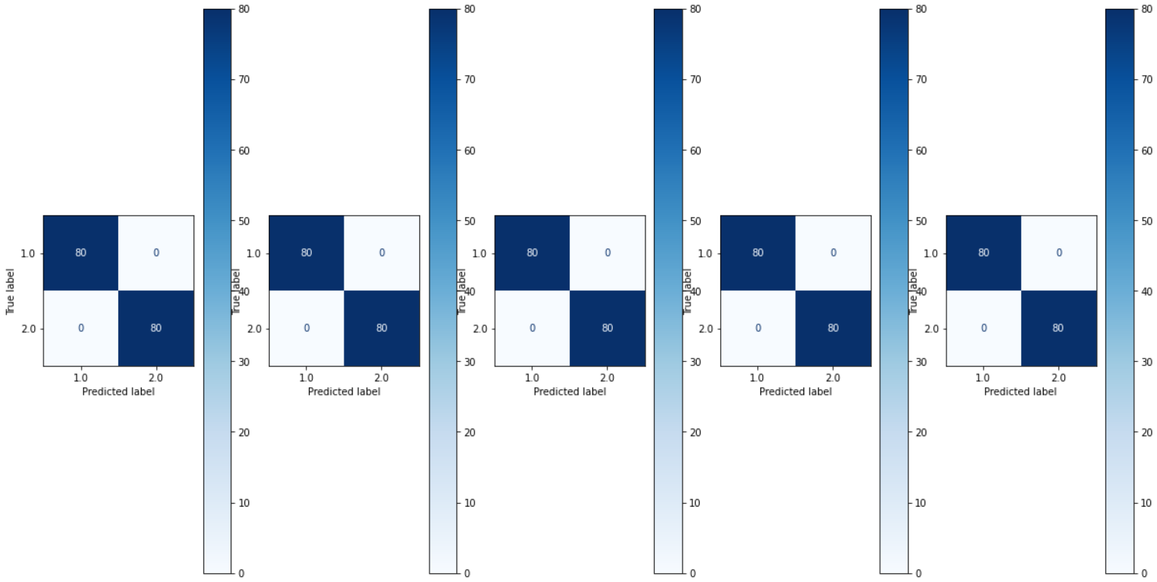
Matriz de confusão

In [19]:

```
plt.figure(figsize=(20, 100))

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    plot_confusion_matrix(mlps[i], X_test, Y_test, cmap='Blues', ax=plt.subplot(
1, 5, i+1))
    i += 1
```



SVM

In [20]:

```
from sklearn.svm import SVC
```

Holdout

In [21]:

```
svm = SVC(kernel='linear')
svm.fit(X_train, Y_train)
```

Out[21]:

```
SVC(C=1.0, break_ties=False, cache_size=200, class_weight=None, coef
0=0.0,
    decision_function_shape='ovr', degree=3, gamma='scale', kernel
='linear',
    max_iter=-1, probability=False, random_state=None, shrinking=Tru
e,
    tol=0.001, verbose=False)
```

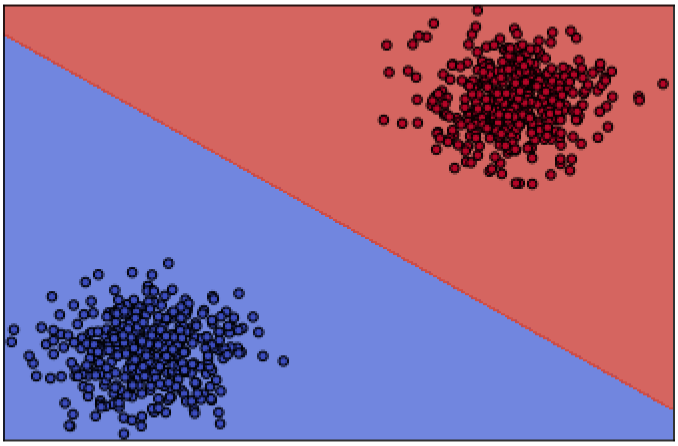
Linha de decisão

In [22]:

```
plot_data_and_boudaries(svm, X, Y)
```

Out[22]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1037eafd0>
```



Acurácia

In [23]:

```
accuracy_score(svm.predict(X_test), Y_test)
```

Out[23]:

```
1.0
```

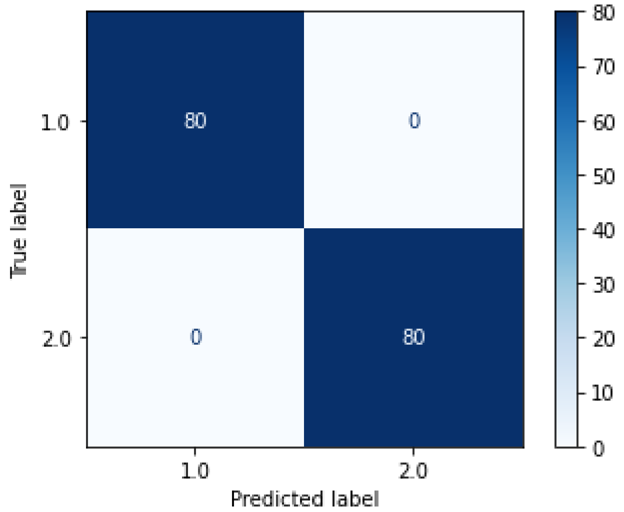
Matriz de confusão

In [24]:

```
plot_confusion_matrix(svm, X_test, Y_test, cmap='Blues')
```

Out[24]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x
11a0bc350>
```



Cross-validation

In [25]:

```
skf = StratifiedKFold()
```

In [26]:

```
svms = []

for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    svm = SVC(kernel='linear')
    svm.fit(X_train, Y_train)
    svms.append(svm)
```

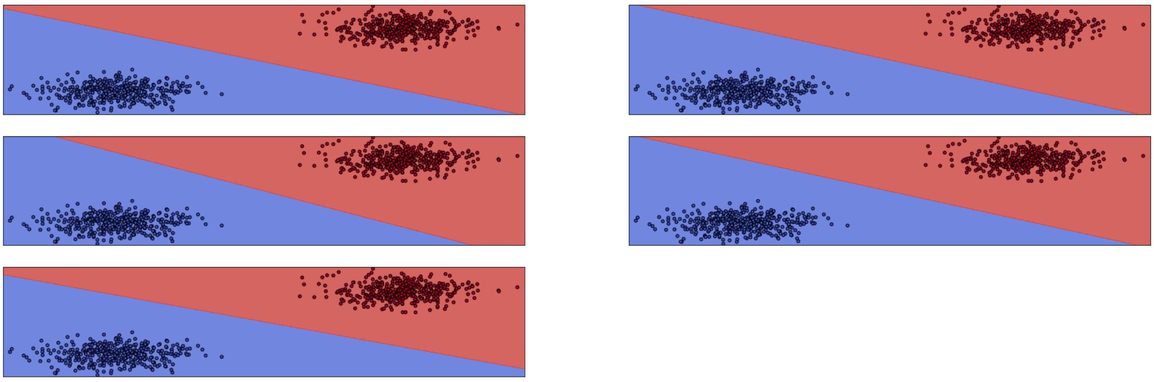
Linha de decisão

In [27]:

```
columns = 2
rows = (skf.get_n_splits() // columns) + 1
rows

plt.figure(figsize=(10 * rows, 10))

for i in range(skf.get_n_splits()):
    plot_data_and_boudaries(svms[i], X, Y, rows, columns, i+1)
```



Acurácia

In [28]:

```
scores = []

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    score = accuracy_score(svms[i].predict(X_test), Y_test)
    scores.append(score)
    i += 1

scores
```

Out[28]:

```
[1.0, 1.0, 1.0, 1.0, 1.0]
```

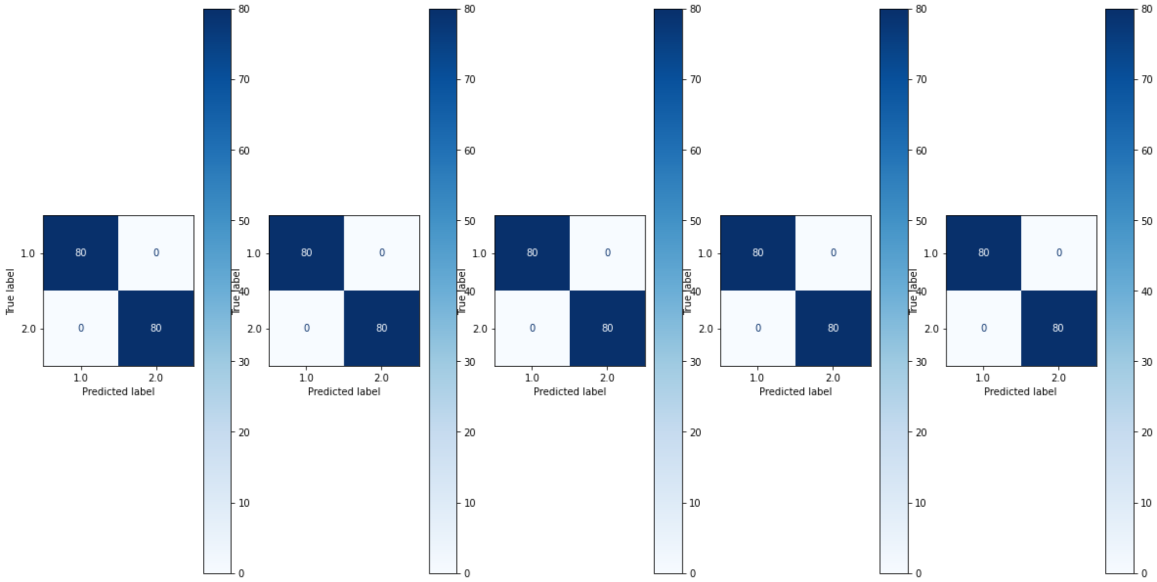
Matriz de confusão

In [29]:

```
plt.figure(figsize=(20, 100))

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    plot_confusion_matrix(svms[i], X_test, Y_test, cmap='Blues', ax=plt.subplot(
1, 5, i+1))
    i += 1
```



Dados2

In [30]:

```
dataset = pd.read_csv('../datasets/dados2.csv')
```

In [31]:

```
dataset.head()
```

Out[31]:

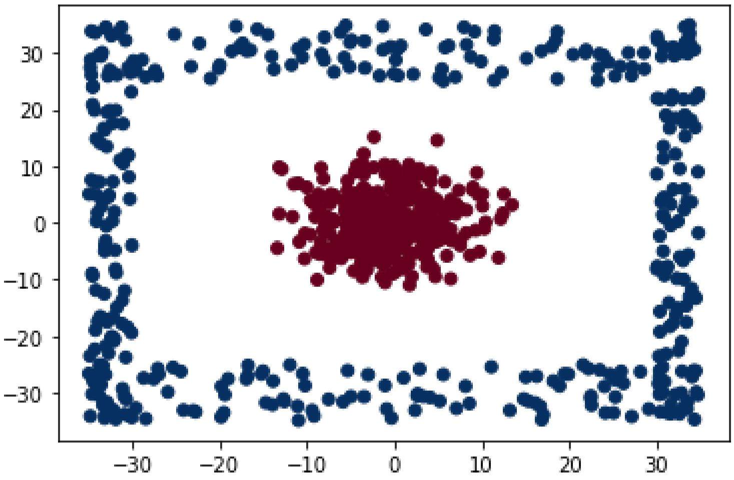
	V1	V2	V3
0	-3.652528	-6.912819	1
1	3.649545	4.693431	1
2	0.611923	6.183120	1
3	6.422804	-9.841413	1
4	-1.840162	-1.126978	1

In [32]:

```
plt.scatter(dataset.V1, dataset.V2, c=dataset.V3, cmap='RdBu')
```

Out[32]:

```
<matplotlib.collections.PathCollection at 0x11a621650>
```



In [33]:

```
X = dataset.values[:, :-1]
Y = dataset.values[:, -1]
```

MLP

In [34]:

```
from sklearn.neural_network import MLPClassifier
```

Holdout

In [35]:

```
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, stratify=Y, random_sta
te=42)
```

In [36]:

```
mlp = MLPClassifier(hidden_layer_sizes=(6), max_iter=5000, random_state=42)
mlp.fit(X_train, Y_train)
```

Out[36]:

```
MLPClassifier(activation='relu', alpha=0.0001, batch_size='auto', be
ta_1=0.9,
              beta_2=0.999, early_stopping=False, epsilon=1e-08,
              hidden_layer_sizes=6, learning_rate='constant',
              learning_rate_init=0.001, max_fun=15000, max_iter=500
0,
              momentum=0.9, n_iter_no_change=10, nesterovs_momentum=
True,
              power_t=0.5, random_state=42, shuffle=True, solver='ad
am',
              tol=0.0001, validation_fraction=0.1, verbose=False,
              warm_start=False)
```

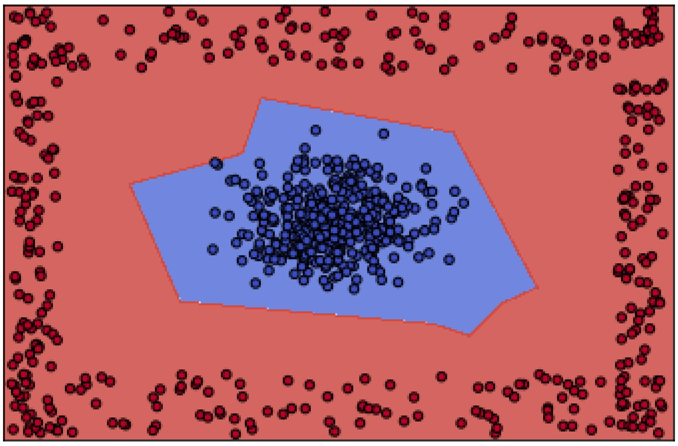
Linha de decisão

In [37]:

```
plot_data_and_boudaries(mlp, X, Y)
```

Out[37]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x11b591cd0>
```



Acurácia

In [38]:

```
accuracy_score(mlp.predict(X_test), Y_test)
```

Out[38]:

```
1.0
```

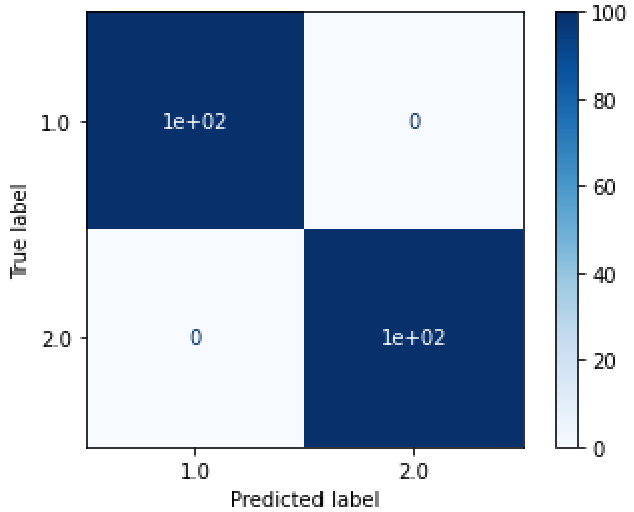
Matriz de confusão

In [39]:

```
plot_confusion_matrix(mlp, X_test, Y_test, cmap='Blues')
```

Out[39]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x
11b09f610>
```



Cross-validation

In [40]:

```
skf = StratifiedKFold()
```

In [41]:

```
mlps = []

for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    mlp = MLPClassifier(hidden_layer_sizes=(6), max_iter=5000, random_state=42)
    mlp.fit(X_train, Y_train)
    mlps.append(mlp)
```

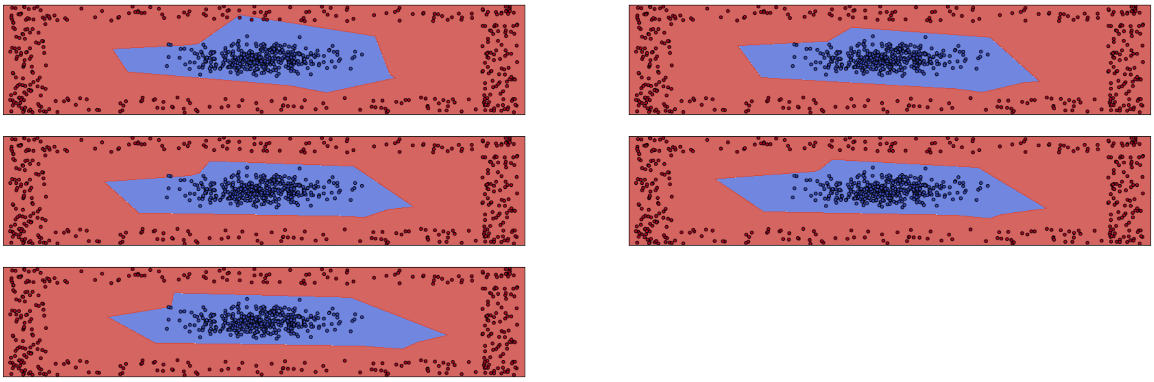
Linha de decisão

In [42]:

```
columns = 2
rows = (skf.get_n_splits() // columns) + 1
rows

plt.figure(figsize=(10 * rows, 10))

for i in range(skf.get_n_splits()):
    plot_data_and_boudaries(mlps[i], X, Y, rows, columns, i+1)
```



Acurácia

In [43]:

```
scores = []

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    score = accuracy_score(mlps[i].predict(X_test), Y_test)
    scores.append(score)
    i += 1

scores
```

Out[43]:

```
[0.98125, 1.0, 0.9875, 1.0, 1.0]
```

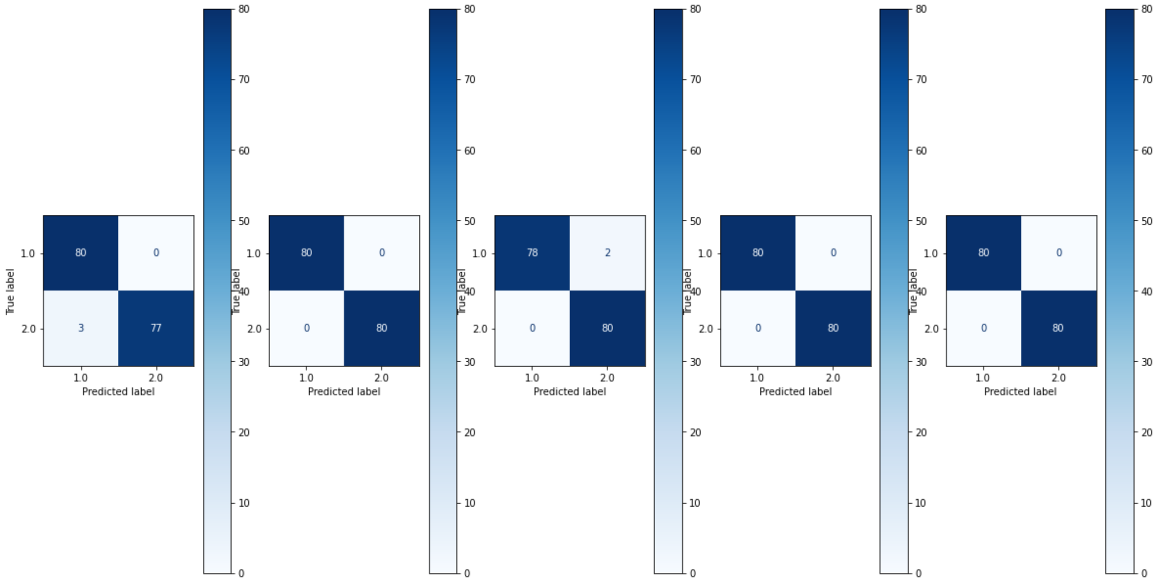
Matriz de confusão

In [44]:

```
plt.figure(figsize=(20, 100))

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    plot_confusion_matrix(mlps[i], X_test, Y_test, cmap='Blues', ax=plt.subplot(
1, 5, i+1))
    i += 1
```



SVM

In [45]:

```
from sklearn.svm import SVC
```

Holdout

In [46]:

```
svm = SVC(kernel='rbf', random_state=42)
svm.fit(X_train, Y_train)
```

Out[46]:

```
SVC(C=1.0, break_ties=False, cache_size=200, class_weight=None, coef
0=0.0,
    decision_function_shape='ovr', degree=3, gamma='scale', kernel
='rbf',
    max_iter=-1, probability=False, random_state=42, shrinking=True,
tol=0.001,
    verbose=False)
```

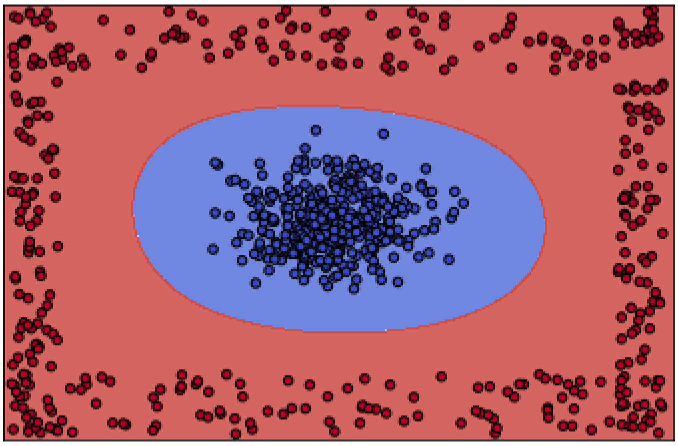
Linha de decisão

In [47]:

```
plot_data_and_boudaries(svm, X, Y)
```

Out[47]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x11aed0f10>
```



Acurácia

In [48]:

```
accuracy_score(svm.predict(X_test), Y_test)
```

Out[48]:

```
1.0
```

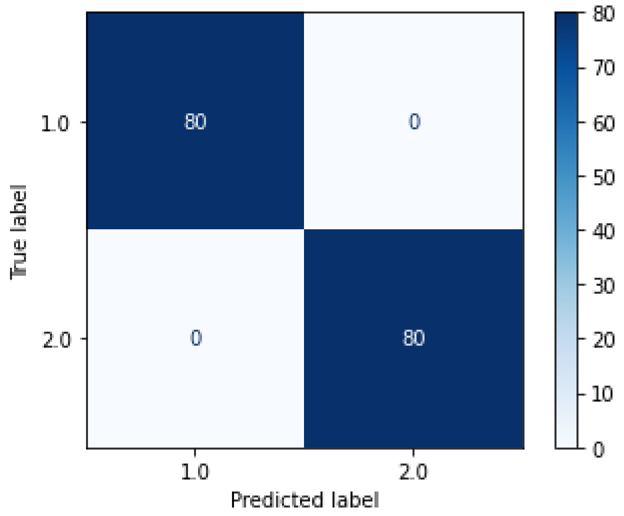
Matriz de confusão

In [49]:

```
plot_confusion_matrix(svm, X_test, Y_test, cmap='Blues')
```

Out[49]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x
11aeba7d0>
```



Cross-validation

In [50]:

```
from sklearn.model_selection import StratifiedKFold

skf = StratifiedKFold()
```

In [51]:

```
svms = []

for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    svm = SVC(kernel='rbf', random_state=42)
    svm.fit(X_train, Y_train)
    svms.append(svm)
```

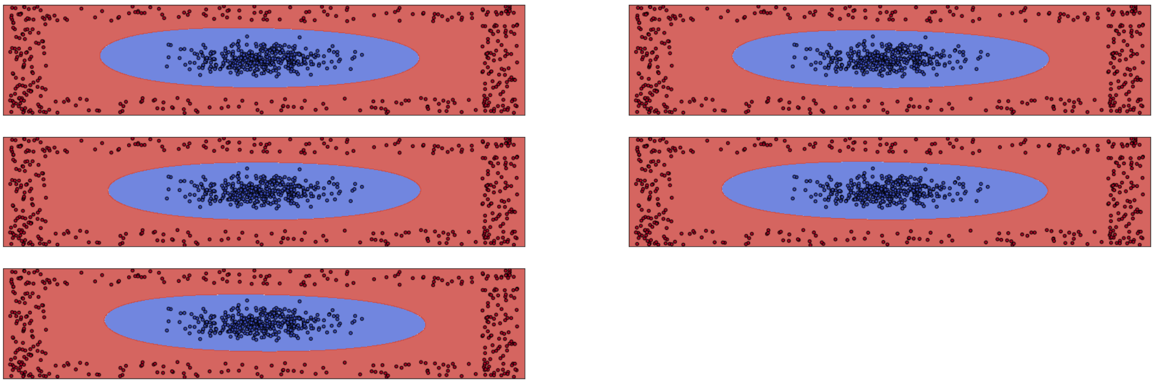
Linha de decisão

In [52]:

```
columns = 2
rows = (skf.get_n_splits() // columns) + 1
rows

plt.figure(figsize=(10 * rows, 10))

for i in range(skf.get_n_splits()):
    plot_data_and_boudaries(svms[i], X, Y, rows, columns, i+1)
```



Acurácia

In [53]:

```
scores = []

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    score = accuracy_score(svms[i].predict(X_test), Y_test)
    scores.append(score)
    i += 1

scores
```

Out[53]:

```
[1.0, 1.0, 1.0, 1.0, 1.0]
```

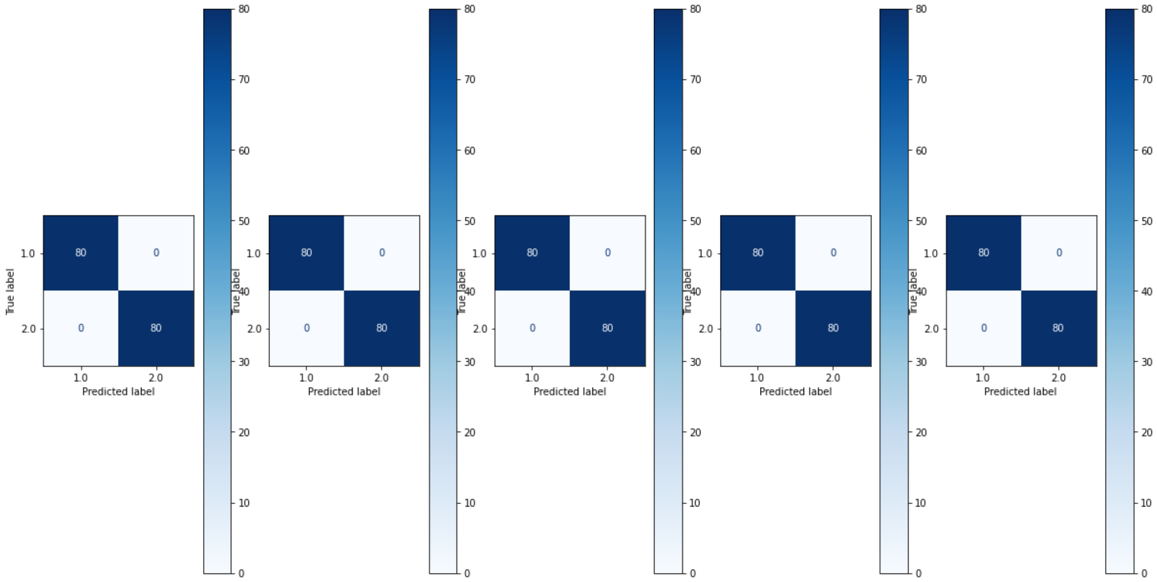
Matriz de confusão

In [54]:

```
plt.figure(figsize=(20, 100))

i = 0
for train_index, test_index in skf.split(X, Y):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]

    plot_confusion_matrix(svms[i], X_test, Y_test, cmap='Blues', ax=plt.subplot(
1, 5, i+1))
    i += 1
```



Conclusões

Apesar de ter o resultado de 100% de acurácia com quantidade suficente de iterações, as MPL apresentam variação quando o método de avaliação utilizado é o K-Fold Cross-Validation. Em contrapartida, o SVM não apresenta essa variação pois consegue traçar a linha de decisão com uma boa margem entre as duas classes

Essa variação das MLP se mostra mais presente ainda quando os dados possuem uma distribuição onde é necessária uma forma 'circular' para separar as classes, como no conjunto de dados 2. No método K-Fold Cross-Validation, os hiperplanos separadores sofreram bastante variação de acordo com qual Fold foi utilizado no treinamento. O que não aconteceu no SVM.

Vale ressaltar que foi necessária a mudança do kernel das SVM de 'linear' para 'rbf'