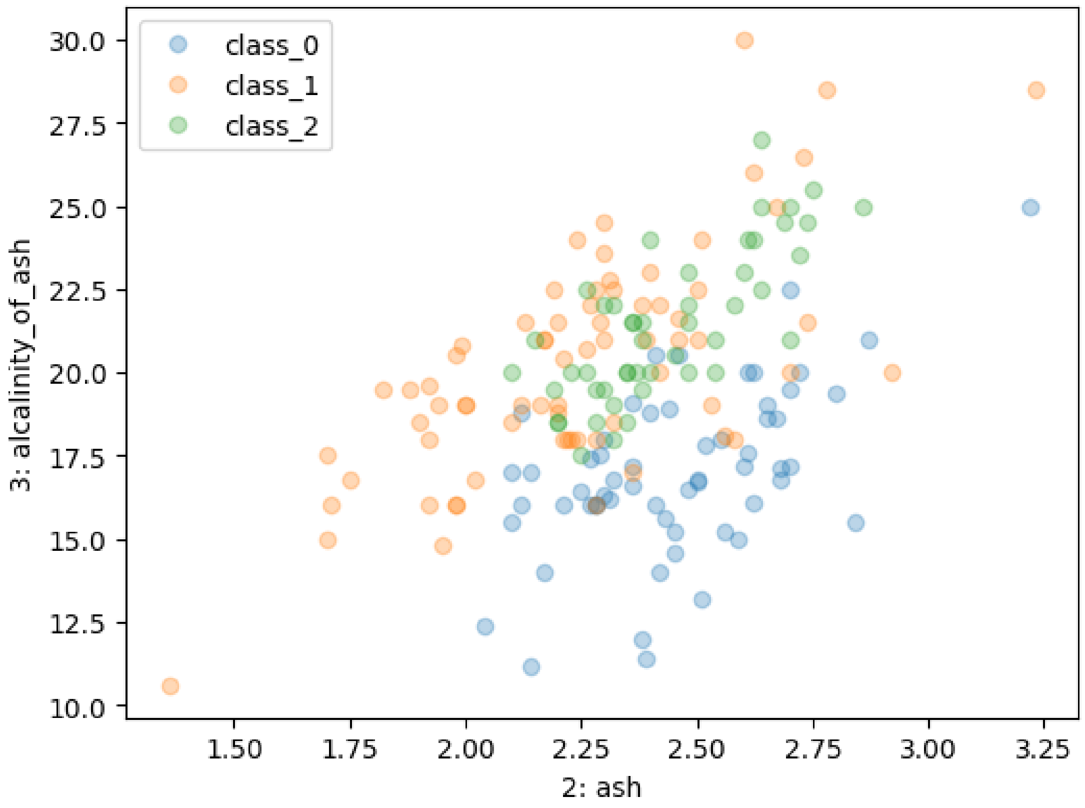
DecisionTree

January 12, 2025

[74]:
```
# from sklearn.datasets import load_iris
# dataset = load_iris()

from sklearn.datasets import load_wine
dataset = load_wine()

X, y = dataset.data, dataset.target
```

[75]:
```
import matplotlib.pyplot as plt
i, j = 2, 3
plt.xlabel(f"{i}: {dataset.feature_names[i]}")
plt.ylabel(f"{j}: {dataset.feature_names[j]}")

for k in set(y):
  plt.plot(X[:,i][y==k], X[:,j][y==k], 'o', alpha=0.3,
           label=f"{dataset.target_names[k]}")
plt.legend()
plt.show()
```



[76]:
```
from sklearn.base import BaseEstimator, ClassifierMixin
from collections import Counter
import numpy as np
from sklearn.model_selection import cross_validate

def maisFrequente(y):
  return Counter(y.flat).most_common(1)[0][0]

class ZeroR(BaseEstimator, ClassifierMixin):
  def fit(self, X, y):
    self.resposta = maisFrequente(y)
    return self
  def predict(self, X, y=None):
    y = np.empty((X.shape[0]))
    y[:] = self.resposta
    return y

scores = cross_validate(ZeroR(), X, y)
scores['test_score'], np.mean(scores['test_score'])
```

[76]:
```
(array([0.        , 0.36111111, 0.        , 0.        , 0.        ]),
 np.float64(0.07222222222222222))
```

[77]:
```
modelo = ZeroR()
modelo.fit(X, y)
modelo.resposta
```

[77]:
```
np.int64(1)
```

[78]:
```
modelo = ZeroR()
modelo.fit(X, y)
ypred = modelo.predict(X)
sum(y==ypred)/len(y)
```

[78]:
```
np.float64(0.398876404494382)
```

[79]:
```
class Arvore(BaseEstimator, ClassifierMixin):
  def fit(self, X, y):
    self.caracteristica = 2
    self.valor = np.mean(X[:,self.caracteristica])
    maiores = X[:,self.caracteristica] > self.valor
    if sum(maiores)>0 and sum(~maiores)>0:
      self.maiores = Arvore()
      self.maiores.fit(X[maiores,:], y[maiores])
      self.menores = Arvore()
      self.menores.fit(X[~maiores,:], y[~maiores])
    else:
      self.resposta = maisFrequente(y)
    return self
  def predict(self, X, y=None):
    y = np.empty((X.shape[0]))
    if hasattr(self, 'resposta'):
      y[:] = self.resposta
    else:
      maiores = X[:,self.caracteristica] > self.valor
      y[maiores] = self.maiores.predict(X[maiores,:])
      y[~maiores] = self.menores.predict(X[~maiores,:])
    return y

modelo = Arvore()
modelo.fit(X, y)
ypred = modelo.predict(X)
sum(y==ypred)/len(y)
```

[79]:
```
np.float64(0.702247191011236)
```

[80]:
```
scores = cross_validate(Arvore(), X, y)
scores['test_score'], np.mean(scores['test_score'])
```

```
[80]: (array([0.05555556, 0.30555556, 0.25      , 0.25714286, 0.14285714]),
       np.float64(0.2022222222222222))
```

```
[81]: def impureza(y): #Gini
        labels = list(set(y))
        labels.sort()
        probabilidades = np.zeros((len(labels),))
        for i, k in enumerate(labels):
          probabilidades[i] = sum(y==k)/len(y)
        result = 1 - sum(probabilidades ** 2)
        return result

      impureza(y[:])
```

```
[81]: np.float64(0.6583133442747129)
```

```
[82]: def impurezaValor(x, y, valor):
        maiores = x > valor
        impurezamaiores = impureza(y[maiores])
        proporcaomaiores = sum(maiores)/len(y)
        impurezamenores = impureza(y[~maiores])
        proporcaomenores = sum(~maiores)/len(y)
        impurezaTotal = proporcaomaiores*impurezamaiores +␣
       ↪proporcaomenores*impurezamenores
        return impurezaTotal, impurezamenores, impurezamaiores

      impurezaValor(X[:,2], y, 2.5)
```

```
[82]: (np.float64(0.6434985114760395),
       np.float64(0.6419753086419754),
       np.float64(0.647189349112426))
```

```
[83]: def melhorValor(x, y):
        result = None
        menorImpureza = float('inf')
        xmax = np.max(x)
        xmin = np.min(x)
        while True:
          valor = (xmin+xmax)/2
          impTotal, impMenores, impMaiores = impurezaValor(x, y, valor)
          if impTotal < menorImpureza:
            menorImpureza = impTotal
            result = valor
            if impMaiores == 0 or impMenores == 0:
              break
            if impMaiores < impMenores:
              xmin = valor
```

```
      else:
        xmax = valor
    else:
      break
  return result, menorImpureza

melhorValor(X[:,2], y)
```

[83]:
```
(np.float64(2.295), np.float64(0.6139307817100282))
```

[84]:
```
def melhorCaracteristica(X, y):
  impurezas = []
  valores = []
  for caracteristica in range(X.shape[1]):
    valor, imp = melhorValor(X[:,caracteristica], y)
    impurezas.append(imp)
    valores.append(valor)
  # print(impurezas)
  # print(valores)
  impurezas = np.array(impurezas)
  caracteristica = np.argmin(impurezas)
  return impurezas[caracteristica], caracteristica, valores[caracteristica]

melhorCaracteristica(X, y)
```

[84]:
```
(np.float64(0.43761750381193476), np.int64(12), np.float64(979.0))
```

[87]:
```
class Arvore(BaseEstimator, ClassifierMixin):
  def fit(self, X, y):
    # if X.shape[1] <= self.caracteristica:
    #     self.caracteristica = X.shape[1] - 1
    self.impureza, self.caracteristica, self.valor = melhorCaracteristica(X, y)
    maiores = X[:,self.caracteristica] > self.valor
    if sum(maiores)>0 and sum(~maiores)>0:
      self.maiores = Arvore()
      self.maiores.fit(X[maiores,:], y[maiores])
      self.menores = Arvore()
      self.menores.fit(X[~maiores,:], y[~maiores])
    else:
      self.resposta = maisFrequente(y)
    return self
  def predict(self, X, y=None):
    y = np.empty((X.shape[0]))
    if hasattr(self, 'resposta'):
      y[:] = self.resposta
    else:
      maiores = X[:,self.caracteristica] > self.valor
      y[maiores] = self.maiores.predict(X[maiores,:])
      y[~maiores] = self.menores.predict(X[~maiores,:])
    return y

modelo = Arvore()
modelo.fit(X, y)
ypred = modelo.predict(X)
sum(y==ypred)/len(y)
```

[87]:
```
np.float64(1.0)
```

0.1 Na função de Melhor Valor

[104]:
```
def melhorValor_novo(x, y):
    if len(x) <= 1:  # Verifique se há valores suficientes
        return None, float("inf")

    # Ordena os valores da característica e os rótulos correspondentes
    sorted_indices = np.argsort(x)
    x_sorted, y_sorted = x[sorted_indices], y[sorted_indices]

    # Calcula as médias consecutivas
    valores_medios = (x_sorted[:-1] + x_sorted[1:]) / 2

    melhor_valor = None
    menor_impureza = float('inf')

    for valor in valores_medios:
        maiores = x > valor
        menores = ~maiores

        # Calcula impurezas para os conjuntos maiores e menores
        impureza_maiores = impureza(y[maiores]) if sum(maiores) > 0 else 0
        impureza_menores = impureza(y[menores]) if sum(menores) > 0 else 0

        # Calcula a impureza total ponderada
        proporcao_maiores = sum(maiores) / len(y)
        proporcao_menores = sum(menores) / len(y)

        impureza_total = (proporcao_maiores * impureza_maiores +
                          proporcao_menores * impureza_menores)

        if impureza_total < menor_impureza:
            menor_impureza = impureza_total
            melhor_valor = valor

    return melhor_valor, menor_impureza
```

0.2 Nova Melhor Característica

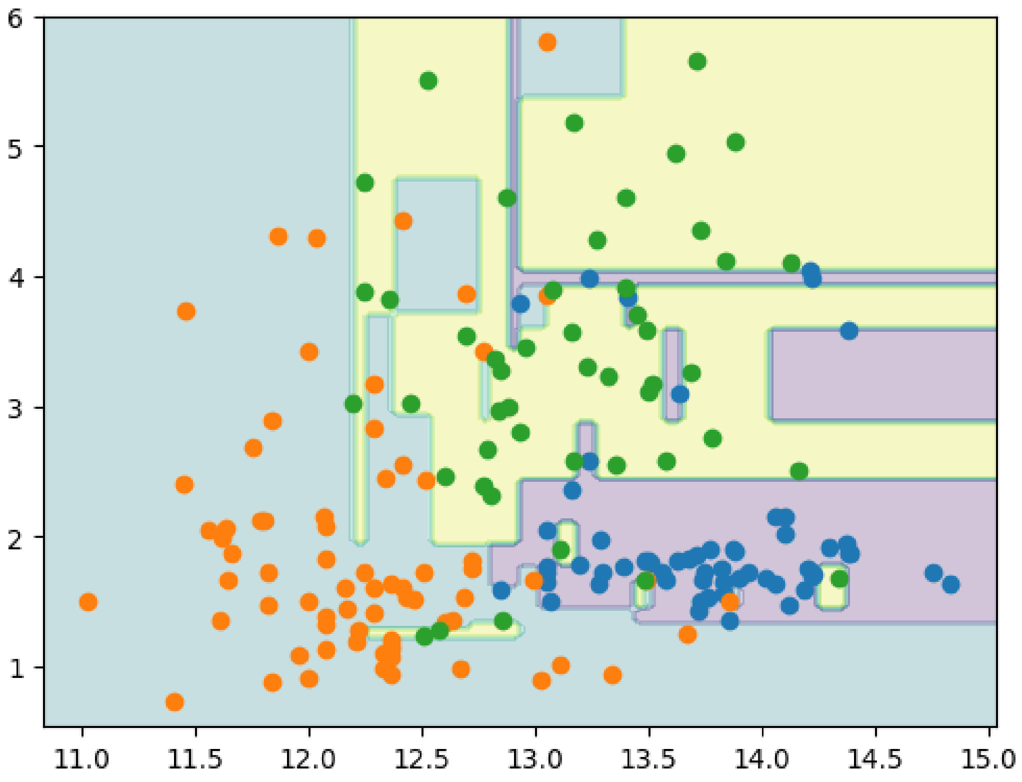
[90]:
```
def melhorCaracteristica_novo(X, y):
    melhor_impureza = float("inf")
    melhor_caracteristica = None
    melhor_valor = None

    # Itera sobre todas as características do conjunto de dados
    for caracteristica in range(X.shape[1]):
        # Encontra o melhor valor de divisão para a característica atual
        valor, impureza = melhorValor_novo(X[:, caracteristica], y)
        if impureza < melhor_impureza:
            melhor_impureza = impureza
            melhor_caracteristica = caracteristica
            melhor_valor = valor

    return melhor_impureza, melhor_caracteristica, melhor_valor
```

[107]:
```
class ArvoreNova(BaseEstimator, ClassifierMixin):
    def __init__(self, heuristica="original"):
        self.heuristica = heuristica

    def fit(self, X, y):
        # Verifica se há dados suficientes para dividir
        if len(X) <= 1:
            self.resposta = Counter(y).most_common(1)[0][0]
            return self

        # Seleciona a melhor característica e valor de divisão
        resultado = melhorCaracteristica_novo(X, y)

        if resultado is None or resultado[1] is None or resultado[2] is None:
            # Caso não encontre um valor válido, atribui a resposta mais␣
↪frequente
            self.resposta = Counter(y).most_common(1)[0][0]
            return self

        self.impureza, self.caracteristica, self.valor = resultado

        # Divide os dados com base no valor selecionado
        maiores = X[:, self.caracteristica] > self.valor
        menores = ~maiores

        if sum(maiores) > 0 and sum(menores) > 0:
            self.maiores = ArvoreNova()
            self.maiores.fit(X[maiores, :], y[maiores])
            self.menores = ArvoreNova()
            self.menores.fit(X[menores, :], y[menores])
        else:
            self.resposta = Counter(y).most_common(1)[0][0]

        return self

    def predict(self, X):
        y = np.empty(X.shape[0], dtype=int)
        if hasattr(self, "resposta"):
            y[:] = self.resposta
        else:
            maiores = X[:, self.caracteristica] > self.valor
            y[maiores] = self.maiores.predict(X[maiores, :])
            y[~maiores] = self.menores.predict(X[~maiores, :])
        return y
```

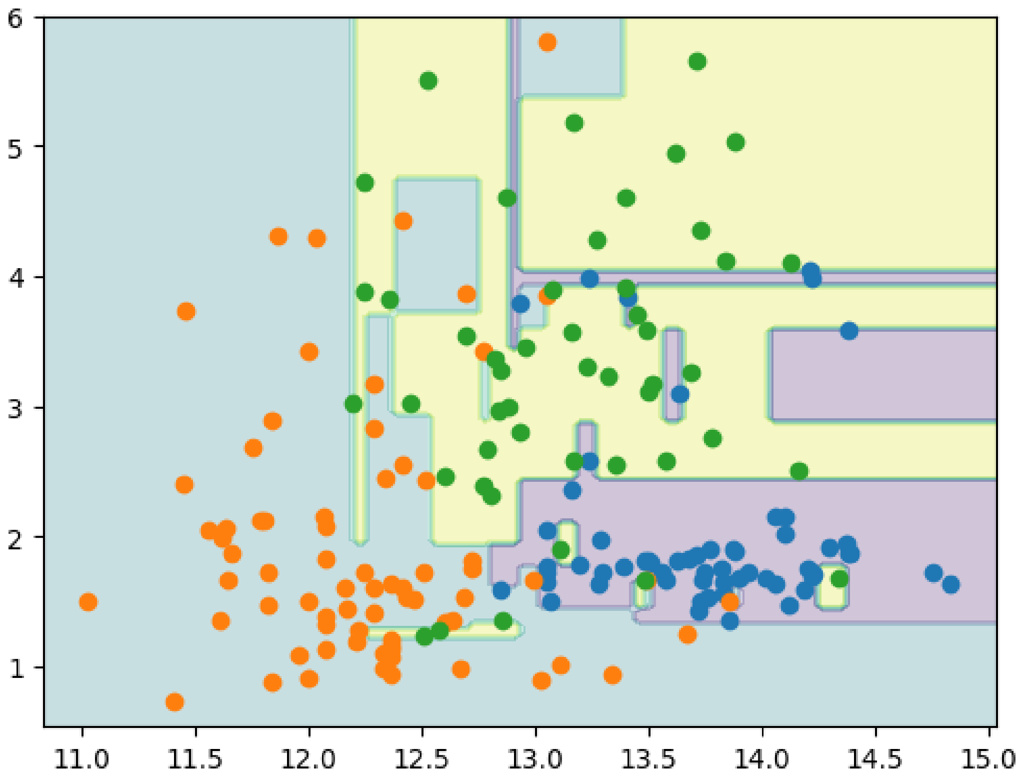
[92]:
```
scores = cross_validate(Arvore(), X, y)
scores['test_score'], np.mean(scores['test_score'])
```

[92]:
```
(array([0.91666667, 0.63888889, 0.86111111, 0.85714286, 0.68571429]),
 np.float64(0.7919047619047619))
```

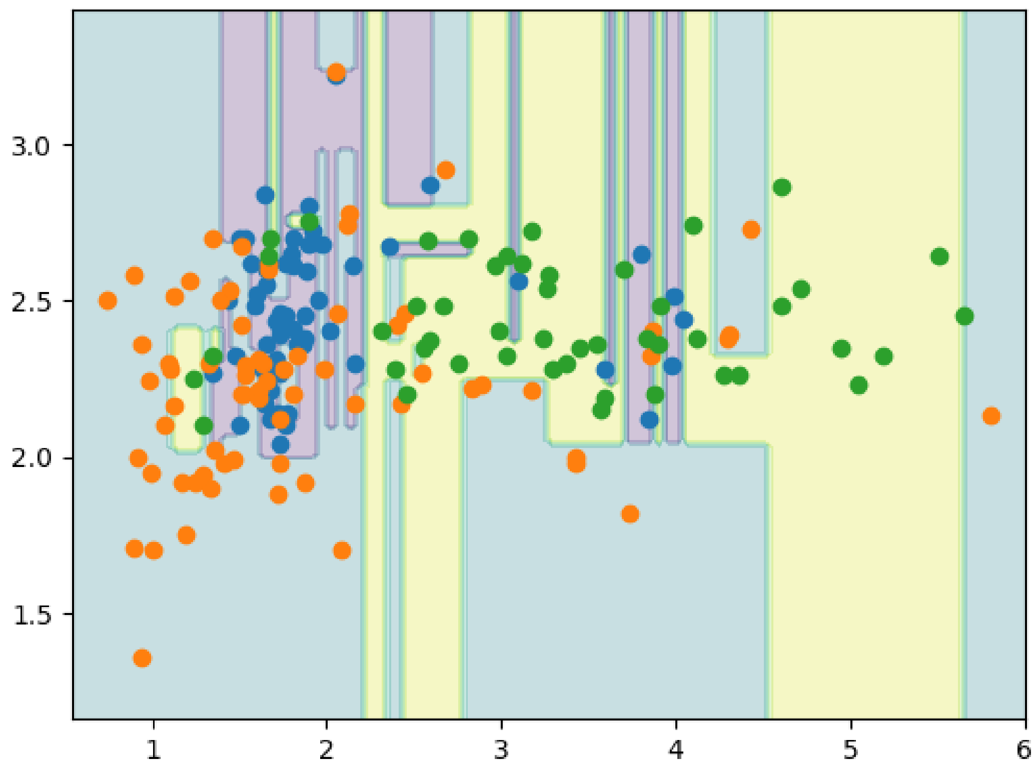
[109]:
```
import matplotlib.pyplot as plt

def plotDecisao(modelo, X, y):
  X = X[:, :2]  # Reduza para 2 dimensões antes de treinar
  modelo.fit(X, y)
  x0s = np.linspace(np.min(X[:,0])-0.2, np.max(X[:,0])+0.2, 100)
  x1s = np.linspace(np.min(X[:,1])-0.2, np.max(X[:,1])+0.2, 100)
  x0, x1 = np.meshgrid(x0s, x1s)
  Xdec = np.c_[x0.ravel(), x1.ravel()]
  ypred = modelo.predict(Xdec)
  plt.contourf(x0, x1, ypred.reshape(x0.shape), alpha=0.25)
  for k in set(y):
    plt.plot(X[:,0][y==k], X[:,1][y==k], 'o')
  plt.show()

plotDecisao(Arvore(), X[:, :], y)
```



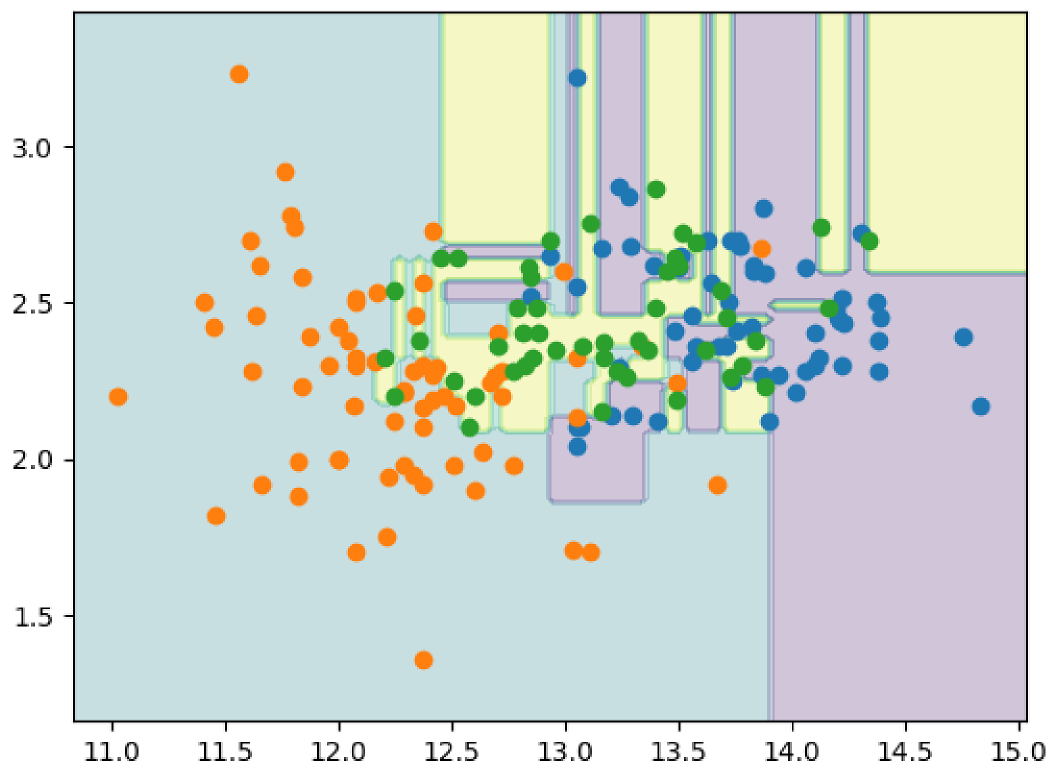
[96]:
```
plotDecisao(Arvore(), X[:,:2], y)
```



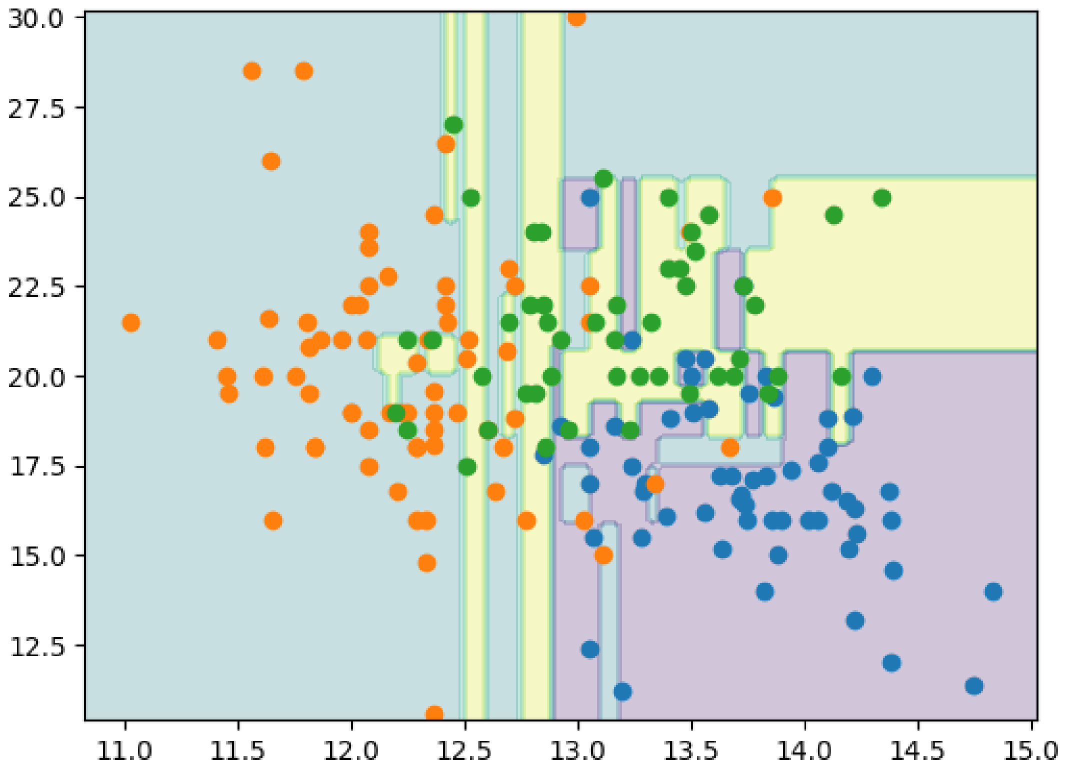
[97]:
```
plotDecisao(Arvore(), X[:,1:3], y)
```



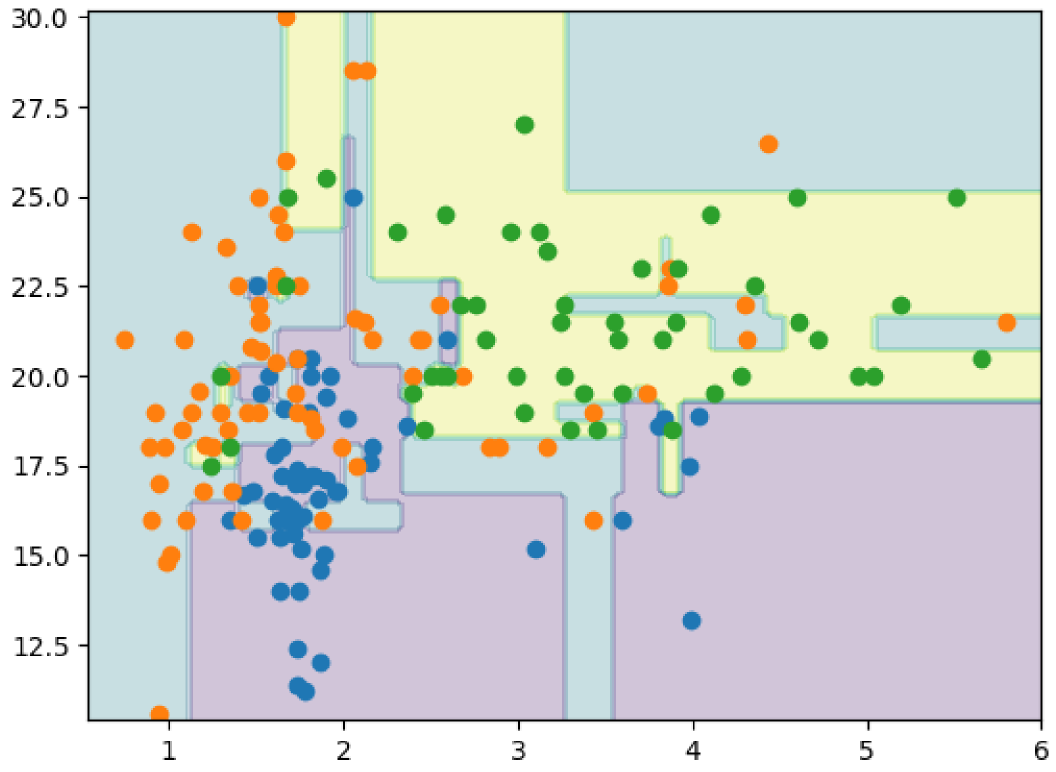
[98]:
```
plotDecisao(Arvore(), X[:,[0,2]], y)
```



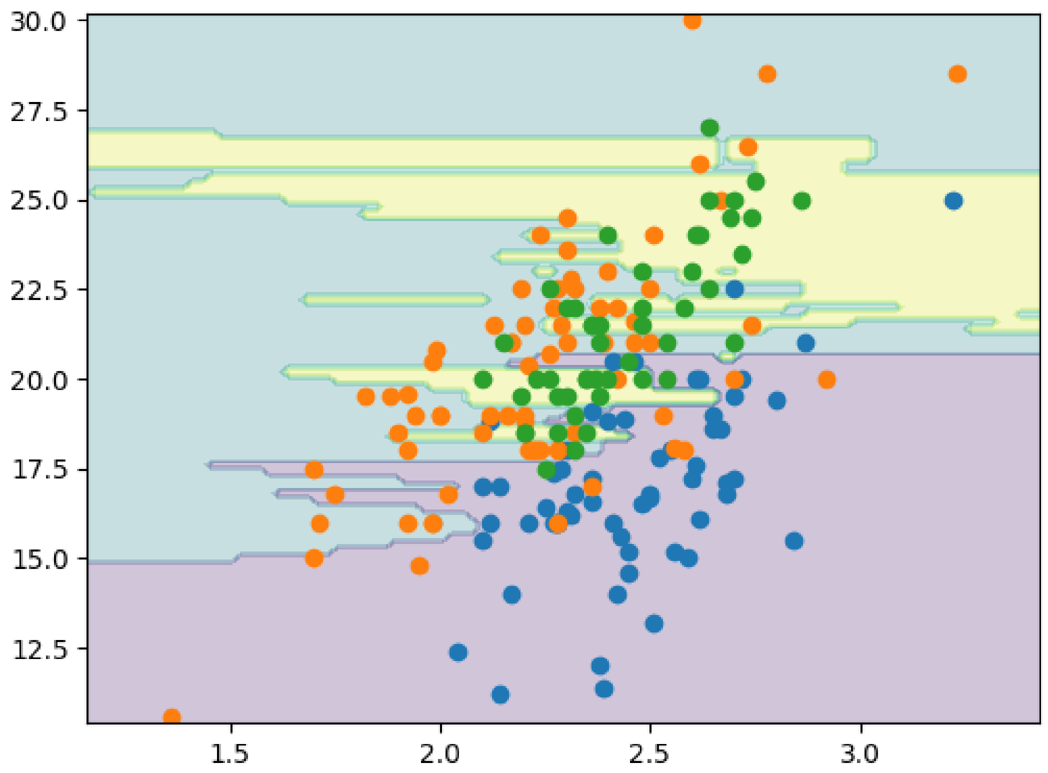
[99]:
```
plotDecisao(Arvore(), X[:,[0,3]], y)
```



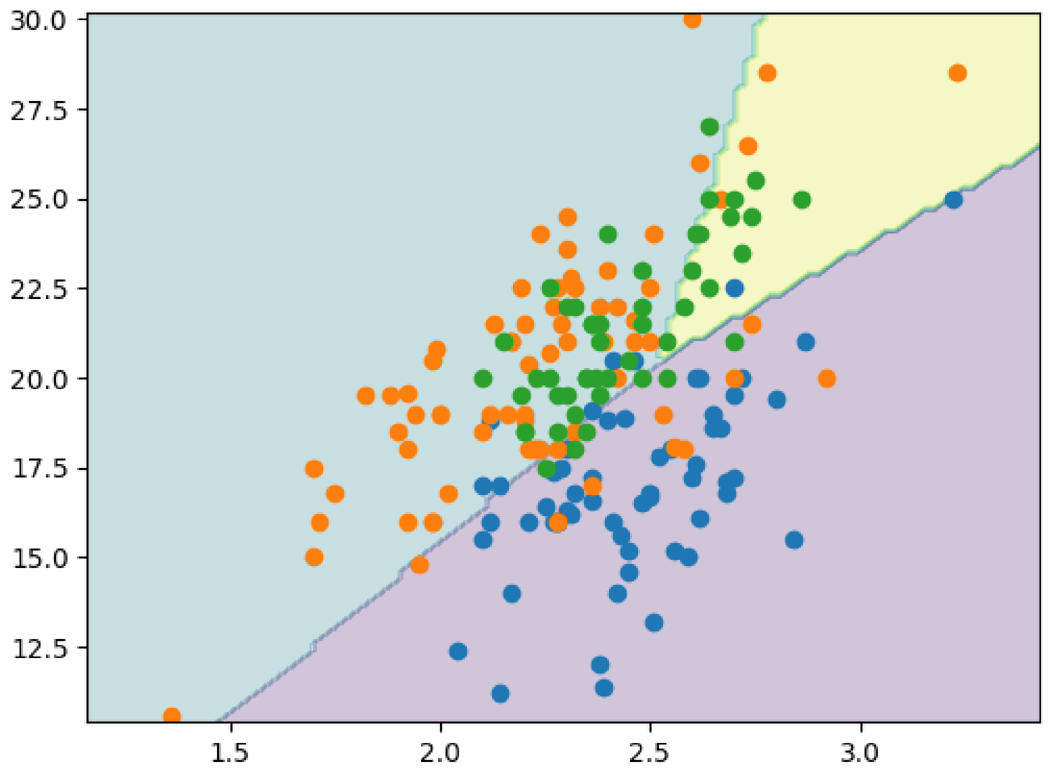
```
[100]: plotDecisao(Arvore(), X[:,[1,3]], y)
```



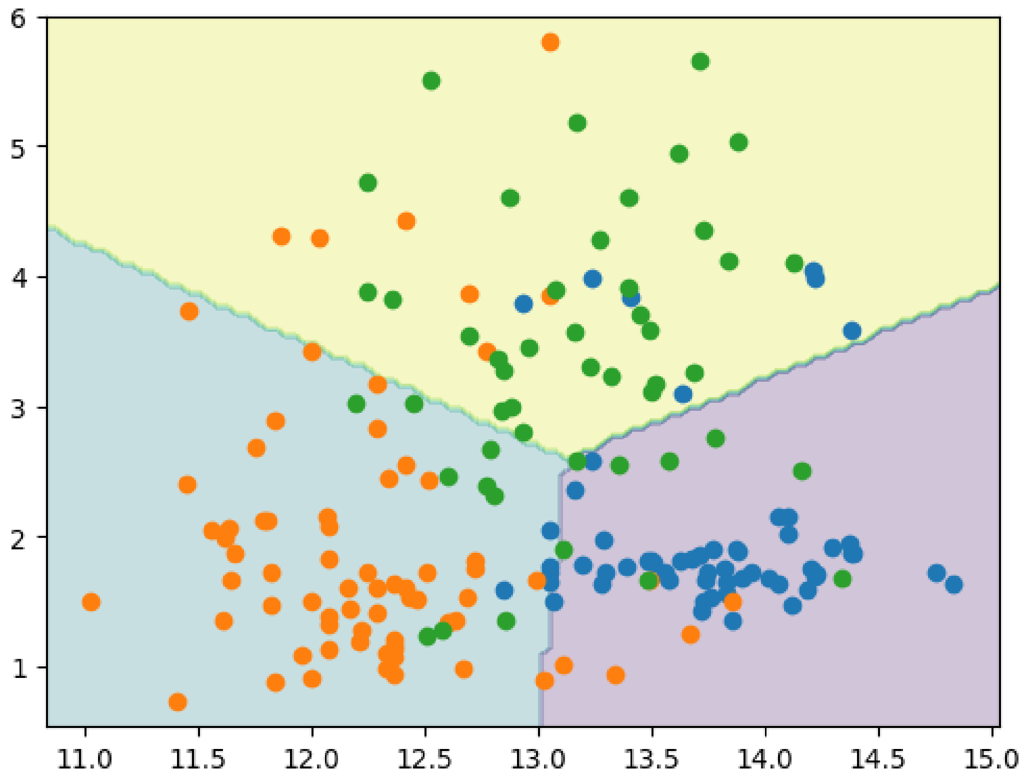
[101]:
```
from sklearn.neighbors import KNeighborsClassifier
plotDecisao(KNeighborsClassifier(), X[:,2:], y)
```



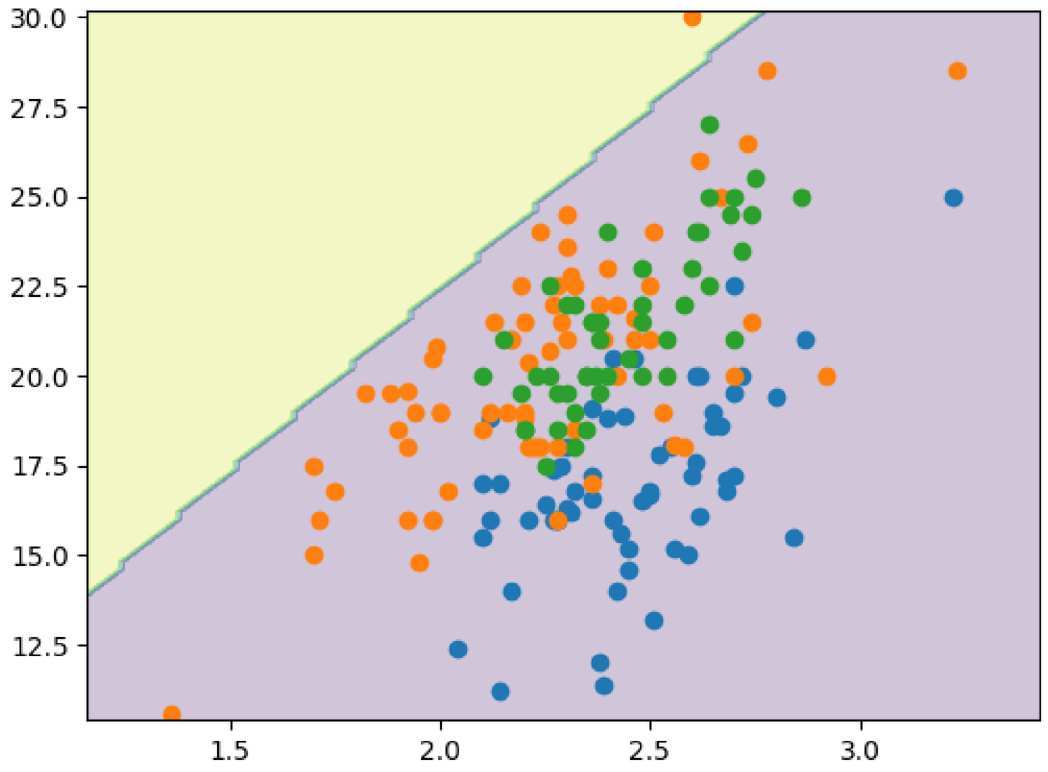
[102]:
```
from sklearn.svm import LinearSVC
plotDecisao(LinearSVC(), X[:,2:], y)
```



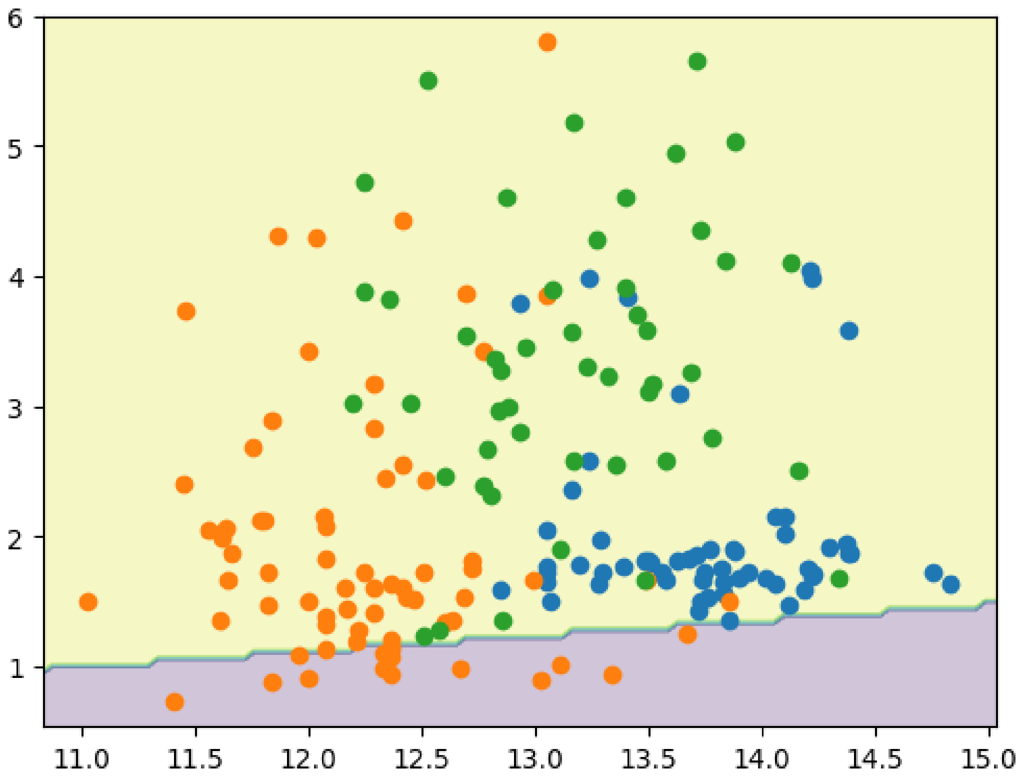
[ ]:
```
plotDecisao(LinearSVC(), X[:,:2], y)
```



```
[ ]: from sklearn.linear_model import Perceptron
     plotDecisao(Perceptron(), X[:,2:], y)
```



```
[ ]: plotDecisao(Perceptron(), X[:,:2], y)
```



0.3 Comparação de desempenho

[110]:
```
import time

# Comparação entre heurísticas
start = time.time()
scores_original = cross_validate(Arvore(), X, y)
tempo_original = time.time() - start

start = time.time()
scores_novo = cross_validate(ArvoreNova(), X, y)
tempo_novo = time.time() - start

# Resultados
print("Heurística Original:")
print("Precisão:", np.mean(scores_original['test_score']))
print("Tempo de Treinamento:", tempo_original)

print("\nHeurística Nova:")
print("Precisão:", np.mean(scores_novo['test_score']))
print("Tempo de Treinamento:", tempo_novo)
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[110], line 9
      6 tempo_original = time.time() - start
      8 start = time.time()
----> 9 scores_novo = cross_validate(ArvoreNova(), X, y)
     10 tempo_novo = time.time() - start
     12 # Resultados

File ~/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/python3.13/
↪site-packages/sklearn/utils/_param_validation.py:216, in validate_params.
↪<locals>.decorator.<locals>.wrapper(*args, **kwargs)
    210 try:
    211     with config_context(
    212         skip_parameter_validation=(
    213             prefer_skip_nested_validation or global_skip_validation
    214         )
    215     ):
--> 216         return func(*args, **kwargs)
    217 except InvalidParameterError as e:
    218     # When the function is just a wrapper around an estimator, we allow
    219     # the function to delegate validation to the estimator, but we␣
↪replace
    220     # the name of the estimator by the name of the function in the erro
    221     # message to avoid confusion.
    222     msg = re.sub(
    223         r"parameter of \w+ must be",
    224         f"parameter of {func.__qualname__} must be",
    225         str(e),
    226     )

File ~/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/python3.13/
↪site-packages/sklearn/model_selection/_validation.py:431, in␣
↪cross_validate(estimator, X, y, groups, scoring, cv, n_jobs, verbose, params,
↪pre_dispatch, return_train_score, return_estimator, return_indices,␣
↪error_score)
    410 parallel = Parallel(n_jobs=n_jobs, verbose=verbose,␣
↪pre_dispatch=pre_dispatch)
    411 results = parallel(
    412     delayed(_fit_and_score)(
    413         clone(estimator),
   (...)
    428     for train, test in indices
    429 )
--> 431 _warn_or_raise_about_fit_failures(results, error_score)
    433 # For callable scoring, the return type is only know after calling. If␣
↪the
    434 # return type is a dictionary, the error scores can now be inserted wit
    435 # the correct key.
    436 if callable(scoring):

File ~/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/python3.13/
 ↪site-packages/sklearn/model_selection/_validation.py:517, in␣
 ↪_warn_or_raise_about_fit_failures(results, error_score)
    510 if num_failed_fits == num_fits:
    511     all_fits_failed_message = (
    512         f"\nAll the {num_fits} fits failed.\n"
    513         "It is very likely that your model is misconfigured.\n"
    514         "You can try to debug the error by setting error_score='raise'.
 ↪\n\n"
    515         f"Below are more details about the failures:
 ↪\n{fit_errors_summary}"
    516     )
--> 517     raise ValueError(all_fits_failed_message)
    519 else:
    520     some_fits_failed_message = (
    521         f"\n{num_failed_fits} fits failed out of a total of {num_fits}.
 ↪\n"
    522         "The score on these train-test partitions for these parameters"
   (…)
    526         f"Below are more details about the failures:
 ↪\n{fit_errors_summary}"
    527     )

ValueError:
All the 5 fits failed.
It is very likely that your model is misconfigured.
You can try to debug the error by setting error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
1 fits failed with the following error:
Traceback (most recent call last):
  File "/Users/otaviolube/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/
 ↪python3.13/site-packages/sklearn/model_selection/_validation.py", line 866, i␣
 ↪_fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
    ~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^

  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
 ↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^

  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
 ↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
```

```
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  [Previous line repeated 17 more times]
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 15, in fit
    maiores = X[:, self.caracteristica] > self.valor
              ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
TypeError: '>' not supported between instances of 'float' and 'NoneType'

--------------------------------------------------------------------------------
1 fits failed with the following error:
Traceback (most recent call last):
  File "/Users/otaviolube/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/
↪python3.13/site-packages/sklearn/model_selection/_validation.py", line 866, i␣
↪_fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
    ~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  [Previous line repeated 35 more times]
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 15, in fit
    maiores = X[:, self.caracteristica] > self.valor
              ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
TypeError: '>' not supported between instances of 'float' and 'NoneType'

--------------------------------------------------------------------------------
2 fits failed with the following error:
Traceback (most recent call last):
  File "/Users/otaviolube/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/
↪python3.13/site-packages/sklearn/model_selection/_validation.py", line 866, i␣
↪_fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
    ~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
```

```
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  [Previous line repeated 47 more times]
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 15, in fit
    maiores = X[:, self.caracteristica] > self.valor
              ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
TypeError: '>' not supported between instances of 'float' and 'NoneType'

--------------------------------------------------------------------------------
1 fits failed with the following error:
Traceback (most recent call last):
  File "/Users/otaviolube/Desktop/pos-devai-ifes/5-int-art-apr-maq/venv/lib/
↪python3.13/site-packages/sklearn/model_selection/_validation.py", line 866, i␣
↪_fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
    ~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 20, in fit
    self.maiores.fit(X[maiores, :], y[maiores])
    ~~~~~~~~~~~~~~~~^^^^^^^^^^^^^^^^^^^^^^^^^^^
  [Previous line repeated 1 more time]
  File "/var/folders/0v/yq16f3tn4rj4w6jh3tnsp47m0000gp/T/ipykernel_63626/
↪3954908824.py", line 15, in fit
    maiores = X[:, self.caracteristica] > self.valor
              ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
TypeError: '>' not supported between instances of 'float' and 'NoneType'
```