# HW4

March 3, 2024

Problem 4.1

[121]:
```
import pandas as pd
import numpy as np

data_path = 'titanic_data.csv'
df = pd.read_csv(data_path)

df['class1'] = (df['Pclass'] == 1).astype(int)
df['class2'] = (df['Pclass'] == 2).astype(int)
df['isFemale'] = df['Sex']
df['isMinor'] = (df['Age'] < 18).astype(int)
df['withSiSp'] = (df['Siblings/Spouses Aboard'] > 0).astype(int)
df['withPaCh'] = (df['Parents/Children Aboard'] > 0).astype(int)
median_fare = df['Fare'].median()
df['highFare'] = (df['Fare'] > median_fare).astype(int)

df.drop(['Age','Sex','Pclass', 'Siblings/Spouses Aboard', 'Parents/Children␣
  ↪Aboard','Fare'], axis=1, inplace=True)
print(df.head())
```

```
   Survived  class1  class2  isFemale  isMinor  withSiSp  withPaCh  highFare
0         0       0       0         0        0         1         0         0
1         1       1       0         1        0         1         0         1
2         1       0       0         1        0         0         0         0
3         1       1       0         1        0         1         0         1
4         0       0       0         0        0         0         0         0
```

Problem 4.2

[122]:
```
def mutual_information(xj, y):
    xj = np.array(xj)
    y = np.array(y)

    p_xj_1 = np.mean(xj == 1)
    p_xj_0 = 1 - p_xj_1
    p_y_1 = np.mean(y == 1)
    p_y_0 = 1 - p_y_1
```

```
    p_xj_0_y_1 = np.mean((xj == 0) & (y == 1))
    p_xj_0_y_0 = np.mean((xj == 0) & (y == 0))
    p_xj_1_y_1 = np.mean((xj == 1) & (y == 1))
    p_xj_1_y_0 = np.mean((xj == 1) & (y == 0))

    mI = 0
    if p_xj_1_y_1 > 0: mI += p_xj_1_y_1 * np.log2(p_xj_1_y_1 / (p_xj_1 * p_y_1))
    if p_xj_1_y_0 > 0: mI += p_xj_1_y_0 * np.log2(p_xj_1_y_0 / (p_xj_1 * p_y_0))
    if p_xj_0_y_1 > 0: mI += p_xj_0_y_1 * np.log2(p_xj_0_y_1 / (p_xj_0 * p_y_1))
    if p_xj_0_y_0 > 0: mI += p_xj_0_y_0 * np.log2(p_xj_0_y_0 / (p_xj_0 * p_y_0))

    return mI
```

Problem 4.3

[153]:
```
class decision_tree_node:
    def __init__(self, feature=None, threshold=None, left=None, right=None,␣
 ↪value=None):
        self.feature = feature
        self.threshold = threshold
        self.left = left
        self.right = right
        self.value = value

class decision_tree:
    def __init__(self, maxDepth=5, minSamplesSplit=10):
        self.root = None
        self.maxDepth = maxDepth
        self.minSamplesSplit = minSamplesSplit

    def fit(self, X, y):
        self.root = self._grow_tree(X, y, depth=0)

    def predict(self, X):
        return np.array([self._predict(inputs, self.root) for inputs in X])

    def _predict(self, inputs, node):
        if node.value is not None:
            return node.value
        if inputs[node.feature] == 0:
            return self._predict(inputs, node.left)
        return self._predict(inputs, node.right)

    def _grow_tree(self, X, y, depth):
        n_samples, n_features = X.shape
        if n_samples == 0 or depth >= self.maxDepth or n_samples < self.
 ↪minSamplesSplit or len(np.unique(y)) == 1:
```

```
            leaf_value = self._most_common_label(y)
            return decision_tree_node(value=leaf_value)

        best_feature, _ = self._best_split(X, y, n_features)

        if best_feature is None:
            leaf_value = self._most_common_label(y)
            return decision_tree_node(value=leaf_value)

        left_idxs, right_idxs = X[:, best_feature] == 0, X[:, best_feature] == 1
        right = self._grow_tree(X[right_idxs], y[right_idxs], depth + 1)
        left = self._grow_tree(X[left_idxs], y[left_idxs], depth + 1)
        return decision_tree_node(feature=best_feature, left=left, right=right)

    def _best_split(self, X, y, n_features):
        best_mi = -1
        split_idx = None
        for feature_idx in range(n_features):
            mi = mutual_information(X[:, feature_idx], y)
            if mi > best_mi:
                best_mi = mi
                split_idx = feature_idx
        return split_idx, best_mi

    def _most_common_label(self, y):
        if len(y) == 0:
            return 0
        else:
            return np.bincount(y).argmax()
```

Problem 4.4

[154]:
```
def print_tree(node, depth=0, feature_names=df.drop('Survived', axis=1).
↪columns, excluded_feature=None):
    prefix = "\t" * depth
    if node.value is not None:
        print(f"{prefix}Predict: {node.value}")
    else:
        if node.feature == excluded_feature:
            print(f"{prefix}Feature '{feature_names[node.feature]}' (excluded)")
        else:
            print(f"{prefix}Feature '{feature_names[node.feature]}'?")
        print(f"{prefix}=> True:")
        print_tree(node.left, depth + 1, feature_names, excluded_feature)
        print(f"{prefix}=> False:")
```

```
        print_tree(node.right, depth + 1, feature_names, excluded_feature)
```

[155]:
```
X = df.drop('Survived', axis=1).values
y = df['Survived'].values

tree = decision_tree()
tree.fit(X, y)

feature_names = list(df.drop('Survived', axis=1).columns)
print_tree(tree.root, feature_names=feature_names)
```

```
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
```

```
                        Feature 'highFare'?
                        => True:
                                Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'class2'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'withPaCh'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
```

```
                                Predict: 1
                        => False:
                                Predict: 1
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
```

Problem 4.5

[126]:
```
from sklearn.model_selection import KFold

kf = KFold(n_splits=10, shuffle=True, random_state=42)

accuracies = []

for train_index, test_index in kf.split(X):
    X_train, X_test = X[train_index], X[test_index]
    y_train, y_test = y[train_index], y[test_index]

    decision_tree = decision_tree(maxDepth=3, minSamplesSplit=20)
    decision_tree.fit(X_train, y_train)

    y_pred = decision_tree.predict(X_test)
    accuracy = np.mean(y_pred == y_test)
    accuracies.append(accuracy)

average_accuracy = np.mean(accuracies)
print(f"Average Accuracy of 10-Fold Cross-Validation : {average_accuracy:.4f}")
```

```
Average 10-Fold Cross-Validation Accuracy: 0.7779
```

Problem 4.6

[127]:
```
x = [0, 1, 0, 0, 0, 1, 1] #class1  class2  isFemale  isMinor  withSiSp ␣
 ↪withPaCh  highFare
prediction = decision_tree.predict(np.array([x]))[0]

if prediction == 1:
    print("I survive the Titanic.")
else:
    print("I dont survive Titanic.")
```

```
I dont survive Titanic.
```

Problem 4.7

[128]:
```
from sklearn.utils import resample
from scipy.stats import mode
class random_forest:
    def __init__(self, n_trees=5, maxDepth=5, minSamplesSplit=10, sample_size=0.
 ↪8):
        self.n_trees = n_trees
        self.maxDepth = maxDepth
        self.minSamplesSplit = minSamplesSplit
        self.sample_size = sample_size
        self.trees = []

    def fit(self, X, y):
        n_features = X.shape[1]
        for _ in range(self.n_trees):
            sample_X, sample_y = resample(X, y, n_samples=int(self.sample_size␣
 ↪* len(y)))
            tree = decision_tree(maxDepth=self.maxDepth, minSamplesSplit=self.
 ↪minSamplesSplit)
            tree.fit(sample_X, sample_y)
            self.trees.append(tree)

    def predict(self, X):
        predictions = [tree.predict(X) for tree in self.trees]
        predictions = np.array(predictions)
        final_prediction, _ = mode(predictions, axis=0)
        return np.squeeze(final_prediction)
```

[129]:
```
def display_random_forest(random_forest, feature_names):
    for i, tree in enumerate(random_forest.trees):
        print(f"Tree {i + 1}:")
        print_tree(tree.root, depth=0, feature_names=feature_names)
        print("-" * 50)
```

[130]:
```
feature_names = ['class1', 'class2', 'isFemale', 'isMinor', 'withSiSp',␣
 ↪'withPaCh', 'highFare']
A = df.drop('Survived', axis=1).values
b = df['Survived'].values
rf_model = random_forest()
rf_model.fit(A, b)
display_random_forest(rf_model, feature_names)
```

```
Tree 1:
Feature 'isFemale'?
=> True:
```

```
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Predict: 1
=> False:
        Feature 'class1'?
        => True:
```

```
                Feature 'class2'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Predict: 1
                => False:
                        Predict: 1
-------------------------------------------------
Tree 2:
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'highFare'?
```

```
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Feature 'highFare'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 0
                                => False:
                                        Predict: 1
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Feature 'highFare'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 0
                                => False:
                                        Feature 'withPaCh'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 0
                        => False:
                                Predict: 1
        => False:
                Feature 'class1'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Feature 'isMinor'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                                => False:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 0
```

```
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Feature 'isMinor'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                                => False:
                                        Predict: 1
                => False:
                        Feature 'withPaCh'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
--------------------------------------------------
Tree 3:
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
```

```
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'class2'?
                => True:
                        Feature 'highFare'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                => False:
                        Feature 'highFare'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
```

```
                                        Predict: 1
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
        => False:
                Feature 'withPaCh'?
                => True:
                        Predict: 1
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
-------------------------------------------------
Tree 4:
Feature 'isFemale'?
=> True:
        Feature 'highFare'?
        => True:
                Feature 'withSiSp'?
                => True:
                        Feature 'class1'?
                        => True:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
```

```
        => False:
                Feature 'class1'?
                => True:
                        Feature 'isMinor'?
                        => True:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 1
=> False:
        Feature 'class2'?
        => True:
                Feature 'class1'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
```

```
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'highFare'?
                => True:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
                => False:
                        Predict: 1
-------------------------------------------------
Tree 5:
Feature 'isFemale'?
=> True:
        Feature 'highFare'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
        => False:
```

```
                Feature 'isMinor'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Feature 'class1'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 1
                                => False:
                                        Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'class2'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'highFare'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                => False:
                        Feature 'highFare'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
```

```
                                Predict: 1
        => False:
                Feature 'withPaCh'?
                => True:
                        Predict: 1
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
--------------------------------------------------
```

[136]:
```
kf2 = KFold(n_splits=10, shuffle=True, random_state=42)
accuracies = []

for train_index, test_index in kf2.split(X):
    X_train, X_test = X[train_index], X[test_index]
    y_train, y_test = y[train_index], y[test_index]

    forest = random_forest()
    forest.fit(X_train, y_train)

    y_pred = forest.predict(X_test)
    accuracy = np.mean(y_pred == y_test)
    accuracies.append(accuracy)

average_accuracy = np.mean(accuracies)
print(f"Average Accuracy of 10-Fold Cross-Validation : {average_accuracy:.4f}")
```

```
Average 10-Fold Cross-Validation Accuracy: 0.8083
```

[137]:
```
k = [0, 1, 0, 0, 0, 1, 1] #class1  class2  isFemale  isMinor  withSiSp
 ↪withPaCh  highFare
prediction = forest.predict(np.array([k]))

if prediction == 1:
    print("I survive the Titanic.")
else:
    print("I dont survive Titanic.")
```

```
I dont survive Titanic.
```

Problem 4.8

[138]:
```
class random_forest_excluding_features:
    def __init__(self, n_trees=6, maxDepth=5, minSamplesSplit=10, sample_size=0.
 ↪8):
        self.n_trees = n_trees
        self.maxDepth = maxDepth
        self.minSamplesSplit = minSamplesSplit
        self.sample_size = sample_size
        self.trees = []

    def predict(self, X):
        tree_predictions = []
        for tree, included_features in self.trees:
            predictions = tree.predict(X[:, included_features])
            tree_predictions.append(predictions)
        tree_predictions = np.array(tree_predictions)
        final_prediction, _ = mode(tree_predictions, axis=0)
        return np.squeeze(final_prediction)

    def fit(self, X, y):
        n_features = X.shape[1]
        # Excludes the class1 & class2 together, then each of the other feature
        feature_combinations = [[0, 1]] + [[i] for i in range(2, n_features)]
        for excluded_features in feature_combinations[:self.n_trees]:
            included_features = [i for i in range(n_features) if i not in␣
 ↪excluded_features]
            sample_X, sample_y = resample(X[:, included_features], y,␣
 ↪n_samples=int(self.sample_size * len(y)))
            tree = decision_tree(maxDepth=self.maxDepth, minSamplesSplit=self.
 ↪minSamplesSplit)
            tree.fit(sample_X, sample_y)
            self.trees.append((tree, included_features))
```

[146]:
```
#b
def cross_validate_random_forest(X, y, n_splits=10):
    kf = KFold(n_splits=n_splits, shuffle=True, random_state=42)
    accuracies = []

    for train_index, test_index in kf.split(X):
        X_train, X_test = X[train_index], X[test_index]
        y_train, y_test = y[train_index], y[test_index]

        rf = random_forest_excluding_features()
        rf.fit(X_train, y_train)
        y_pred = rf.predict(X_test)
        accuracy = np.mean(y_pred == y_test)
```

```
        accuracies.append(accuracy)
    average_accuracy = np.mean(accuracies)
    return average_accuracy

T = A
u = b

average_accuracy = cross_validate_random_forest(T, u)
print(f"Average Accuracy of 10-Fold Cross-Validation : {average_accuracy:.4f}")
```

```
Average accuracy from 10-fold cross-validation: 0.8117
```

[151]:
```
#a
def display_random_forest_excluding_features(random_forest, feature_names):
    for i, (tree, included_features) in enumerate(random_forest.trees):
        print(f"Tree {i + 1} (Excluding features: {[feature_names[idx] for idx␣
 ↪in range(len(feature_names)) if idx not in included_features]}):")
        print_tree(tree.root, depth=0, feature_names=[feature_names[idx] for␣
 ↪idx in included_features])
        print("-" * 50)
```

[152]:
```
rf = random_forest_excluding_features()
rf.fit(T, u)
display_random_forest_excluding_features(rf, feature_names)
```

```
Tree 1 (Excluding features: ['class1', 'class2']):
Feature 'isFemale'?
=> True:
        Feature 'isMinor'?
        => True:
                Feature 'highFare'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'isFemale'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'withPaCh'?
```

```
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
        => False:
                Feature 'withPaCh'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
=> False:
        Feature 'withSiSp'?
        => True:
                Feature 'highFare'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
                => False:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'isFemale'?
```

```
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'highFare'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                => False:
                        Feature 'highFare'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
-------------------------------------------------
Tree 2 (Excluding features: ['isFemale']):
Feature 'highFare'?
=> True:
        Feature 'class2'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'class1'?
                                => True:
```

```
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'withPaCh'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 0
                => False:
                        Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'withPaCh'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withSiSp'?
                                => True:
```

```
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 0
                                => False:
                                        Feature 'isMinor'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 1
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                                => False:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                        => False:
                                Predict: 1
--------------------------------------------------
Tree 3 (Excluding features: ['isMinor']):
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'withPaCh'?
                => True:
                        Feature 'highFare'?
                        => True:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
```

```
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
        => False:
                Feature 'withSiSp'?
                => True:
                        Feature 'highFare'?
                        => True:
                                Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 0
=> False:
        Feature 'class2'?
        => True:
                Feature 'class1'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
```

```
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
        => False:
                Feature 'withSiSp'?
                => True:
                        Predict: 1
                => False:
                        Feature 'highFare'?
                        => True:
                                Predict: 1
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
------------------------------------------------
Tree 4 (Excluding features: ['withSiSp']):
Feature 'isFemale'?
=> True:
        Feature 'highFare'?
        => True:
                Feature 'withPaCh'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
```

```
                                        Predict: 0
                        => False:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'class2'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'class2'?
                => True:
                        Feature 'highFare'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
```

```
                                Feature 'isMinor'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Feature 'highFare'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                                => False:
                                        Predict: 1
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Feature 'class1'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
------------------------------------------------
Tree 5 (Excluding features: ['withPaCh']):
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
```

```
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'class2'?
                                => True:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 0
                                => False:
                                        Predict: 1
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Predict: 0
                                => False:
                                        Feature 'withSiSp'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 0
                        => False:
                                Predict: 1
        => False:
                Feature 'class1'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'highFare'?
                                => True:
                                        Feature 'isMinor'?
                                        => True:
                                                Predict: 1
                                        => False:
                                                Predict: 1
                                => False:
                                        Feature 'isMinor'?
                                        => True:
                                                Predict: 0
                                        => False:
                                                Predict: 0
                        => False:
                                Feature 'isMinor'?
                                => True:
                                        Feature 'withSiSp'?
```

```
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                => False:
                        Predict: 1
-------------------------------------------------
Tree 6 (Excluding features: ['highFare']):
Feature 'isFemale'?
=> True:
        Feature 'class1'?
        => True:
                Feature 'isMinor'?
                => True:
                        Feature 'class2'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                => False:
                        Feature 'class2'?
                        => True:
```

```
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 1
        => False:
                Feature 'withSiSp'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'class1'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 0
                        => False:
                                Predict: 0
                => False:
                        Feature 'isMinor'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 0
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
=> False:
        Feature 'class1'?
        => True:
                Feature 'class2'?
                => True:
                        Feature 'withPaCh'?
                        => True:
                                Feature 'isMinor'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 0
                => False:
```

```
                        Feature 'isMinor'?
                        => True:
                                Feature 'withSiSp'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
        => False:
                Feature 'isMinor'?
                => True:
                        Feature 'withSiSp'?
                        => True:
                                Feature 'withPaCh'?
                                => True:
                                        Predict: 1
                                => False:
                                        Predict: 1
                        => False:
                                Predict: 1
                => False:
                        Predict: 1
--------------------------------------------------
```

[150]:
```c
#c
s = [0, 1, 0, 0, 0, 1, 1]
prediction = rf.predict(np.array([s]))

if prediction == 1:
    print("I survive the Titanic.")
else:
    print("I dont survive Titanic.")
```

```
I dont survive Titanic.
```