Chapter 6 – Decision Trees

This notebook contains all the sample code and solutions to the exercises in chapter 6.

Setup

This project requires Python 3.7 or above:

In [1]:
```
import sys

assert sys.version_info >= (3, 7)
```

It also requires Scikit-Learn ≥ 1.0.1:

In [2]:
```
from packaging import version
import sklearn

assert version.parse(sklearn.__version__) >= version.parse("1.0.1")
```

As we did in previous chapters, let's define the default font sizes to make the figures prettier:

In [3]:
```
import matplotlib.pyplot as plt

plt.rc('font', size=14)
plt.rc('axes', labelsize=14, titlesize=14)
plt.rc('legend', fontsize=14)
plt.rc('xtick', labelsize=10)
plt.rc('ytick', labelsize=10)
```

And let's create the `images/decision_trees` folder (if it doesn't already exist), and define the `save_fig()` function which is used through this notebook to save the figures in high-res for the book:

In [4]:
```
from pathlib import Path

IMAGES_PATH = Path() / "images" / "decision_trees"
IMAGES_PATH.mkdir(parents=True, exist_ok=True)

def save_fig(fig_id, tight_layout=True, fig_extension="png", resolution=300):
    path = IMAGES_PATH / f"{fig_id}.{fig_extension}"
    if tight_layout:
        plt.tight_layout()
    plt.savefig(path, format=fig_extension, dpi=resolution)
```

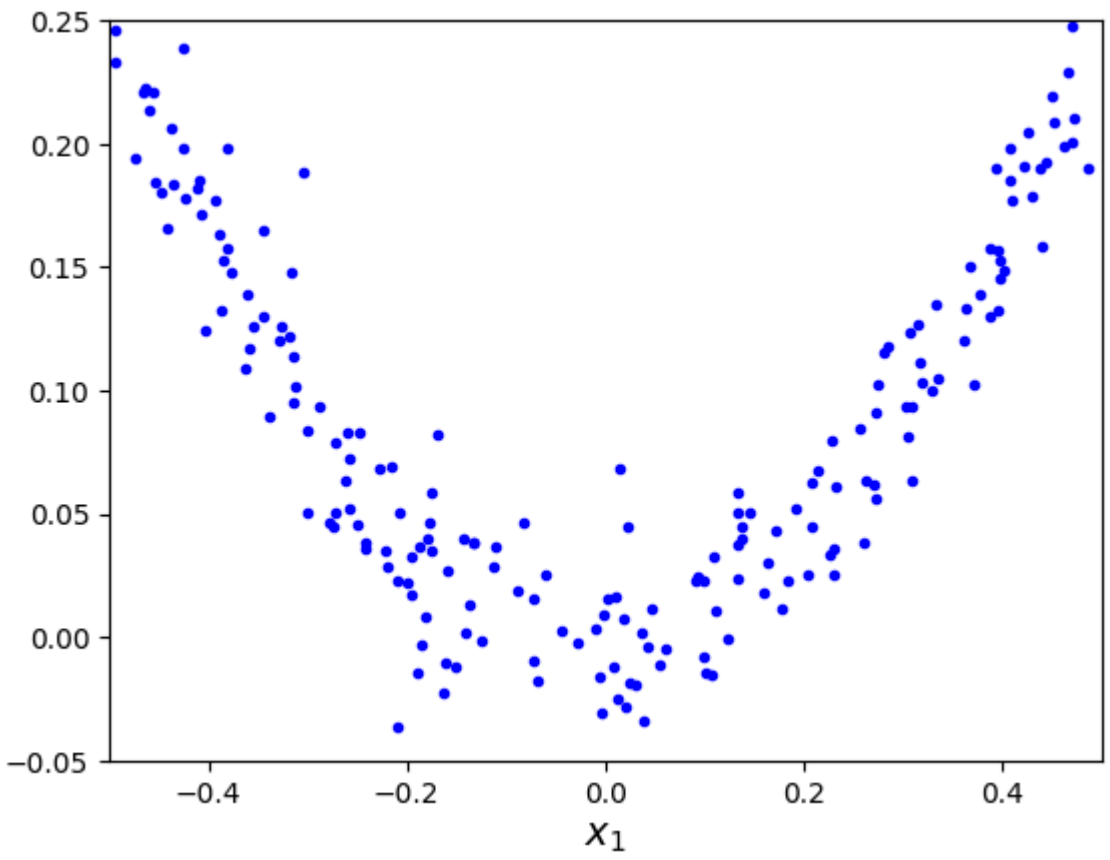
Regression

Let's prepare a simple quadratic training set:

Code example:

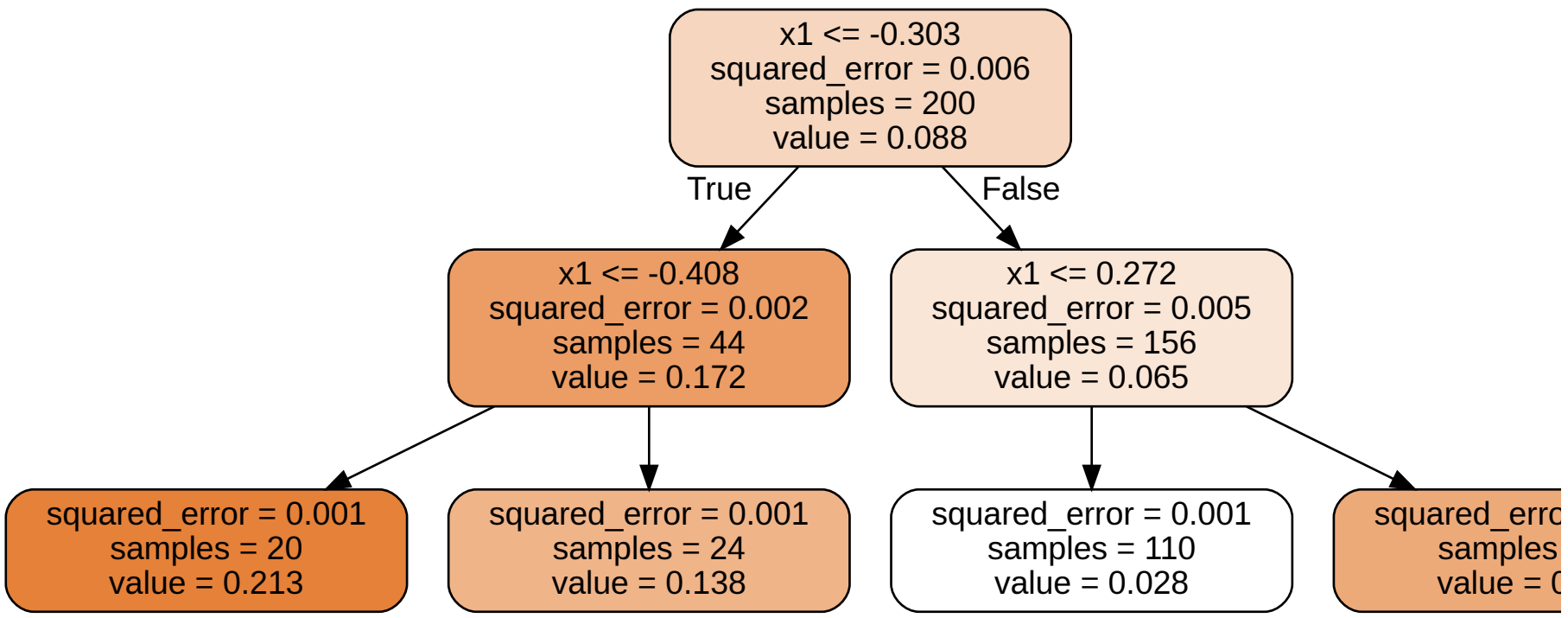
In [5]:
```
from sklearn.tree import DecisionTreeRegressor
import numpy as np

np.random.seed(42)
X_quad = np.random.rand(200, 1) - 0.5  # a single random input feature
y_quad = X_quad ** 2 + 0.025 * np.random.randn(200, 1)

axes=[-0.5, 0.5, -0.05, 0.25]
x1 = np.linspace(axes[0], axes[1], 500).reshape(-1, 1)
plt.axis(axes)
plt.xlabel("$x_1$")
plt.plot(X_quad, y_quad, "b.")

tree_reg = DecisionTreeRegressor(max_depth=2, random_state=42)
tree_reg.fit(X_quad, y_quad)
```

Out[5]:
```
▾ DecisionTreeRegressor ⓘ ?

▸ Parameters
```



In [6]:
```
from sklearn.tree import export_graphviz
from graphviz import Source

# extra code – we've already seen how to use export_graphviz()
export_graphviz(
    tree_reg,
    out_file=str(IMAGES_PATH / "regression_tree.dot"),
    feature_names=["x1"],
    rounded=True,
    filled=True
)
Source.from_file(IMAGES_PATH / "regression_tree.dot")
```

Out[6]:



In [7]:
```
tree_reg2 = DecisionTreeRegressor(max_depth=3, random_state=42)
tree_reg2.fit(X_quad, y_quad)
```

Out[7]:

▾ DecisionTreeRegressor ⓘ ?

▸ Parameters

In [8]:
```
tree_reg.tree_.threshold
```

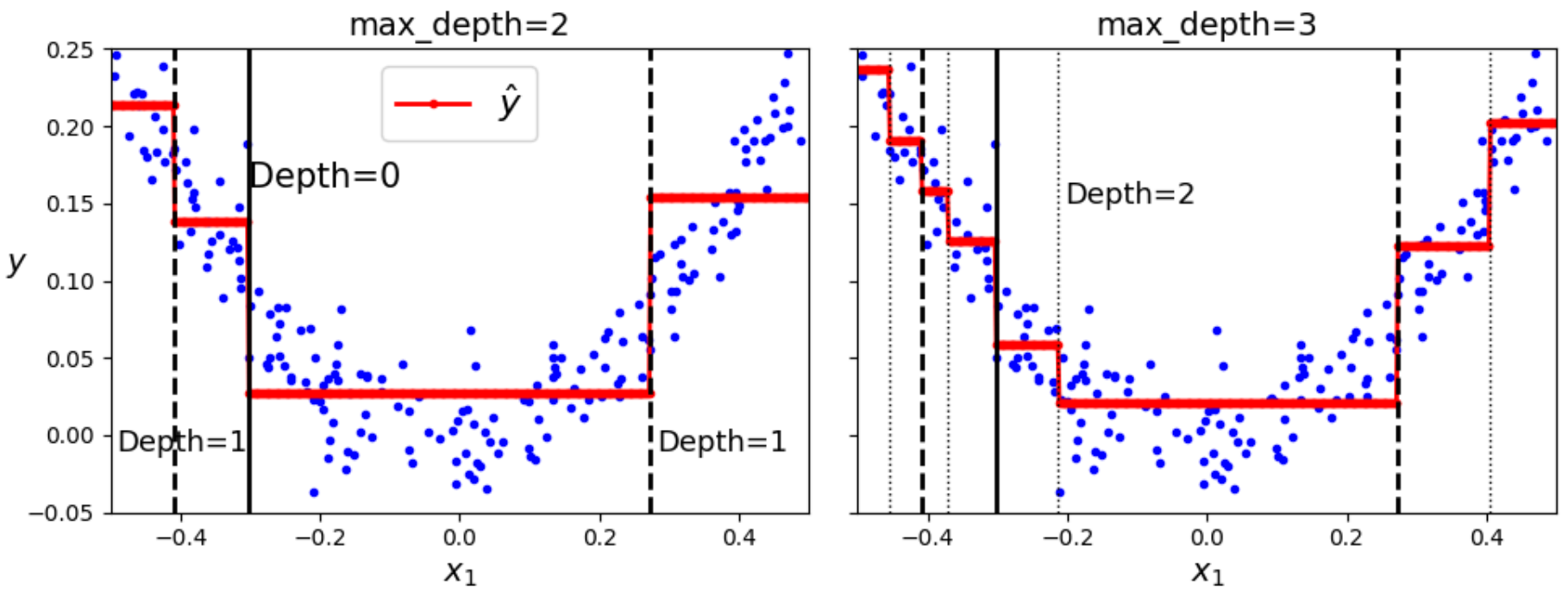
Out[8]:
```
array([-0.30265072, -0.40830374, -2.        , -2.        ,  0.27175756,
       -2.        , -2.        ])
```

In [9]:
```
tree_reg2.tree_.threshold
```

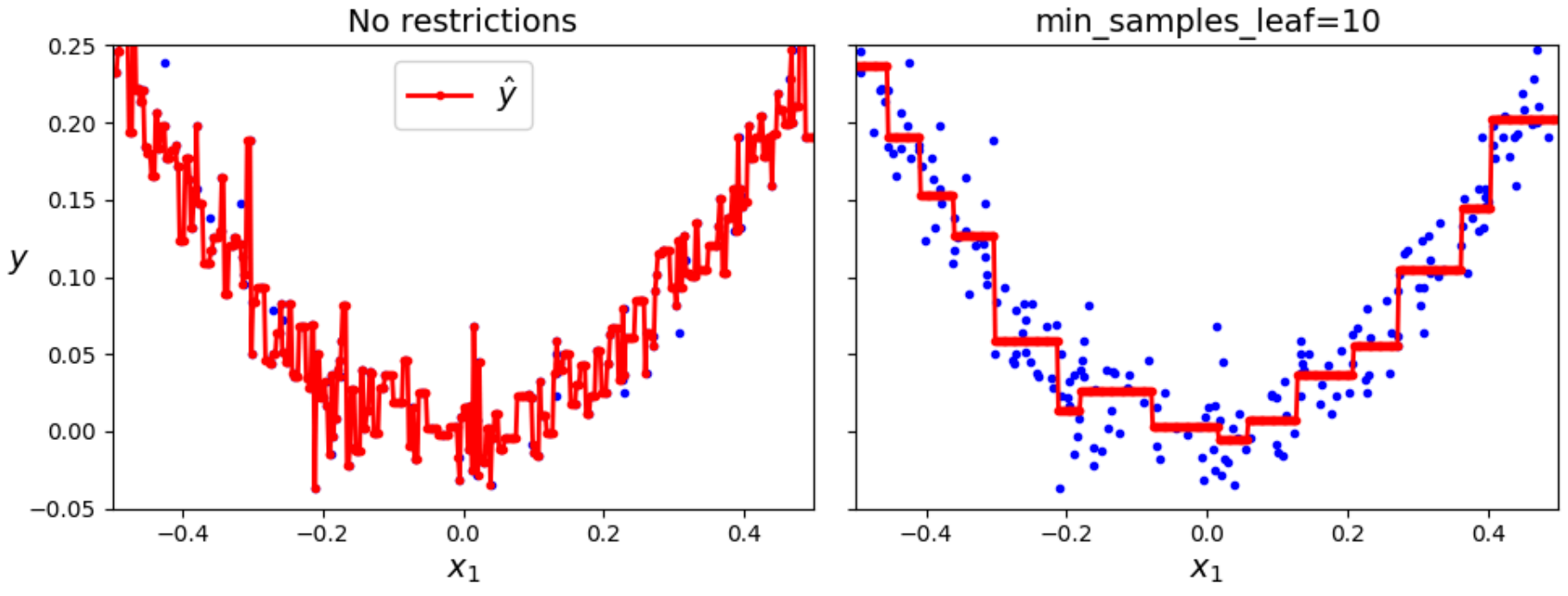
Out[9]:
```
array([-0.30265072, -0.40830374, -0.45416115, -2.        , -2.        ,
       -0.37022041, -2.        , -2.        ,  0.27175756, -0.21270403,
       -2.        , -2.        ,  0.40399227, -2.        , -2.        ])
```

In [10]:
```
# extra code – this cell generates and saves Figure 6–5

def plot_regression_predictions(tree_reg, X, y, axes=[-0.5, 0.5, -0.05, 0.25]):
    x1 = np.linspace(axes[0], axes[1], 500).reshape(-1, 1)
    y_pred = tree_reg.predict(x1)
```

```
    plt.axis(axes)
    plt.xlabel("$x_1$")
    plt.plot(X, y, "b.")
    plt.plot(x1, y_pred, "r.-", linewidth=2, label=r"$\hat{y}$")

fig, axes = plt.subplots(ncols=2, figsize=(10, 4), sharey=True)
plt.sca(axes[0])
plot_regression_predictions(tree_reg, X_quad, y_quad)

th0, th1a, th1b = tree_reg.tree_.threshold[[0, 1, 4]]
for split, style in ((th0, "k-"), (th1a, "k--"), (th1b, "k--")):
    plt.plot([split, split], [-0.05, 0.25], style, linewidth=2)
plt.text(th0, 0.16, "Depth=0", fontsize=15)
plt.text(th1a + 0.01, -0.01, "Depth=1", horizontalalignment="center", fontsize=13)
plt.text(th1b + 0.01, -0.01, "Depth=1", fontsize=13)
plt.ylabel("$y$", rotation=0)
plt.legend(loc="upper center", fontsize=16)
plt.title("max_depth=2")

plt.sca(axes[1])
th2s = tree_reg2.tree_.threshold[[2, 5, 9, 12]]
plot_regression_predictions(tree_reg2, X_quad, y_quad)
for split, style in ((th0, "k-"), (th1a, "k--"), (th1b, "k--")):
    plt.plot([split, split], [-0.05, 0.25], style, linewidth=2)
for split in th2s:
    plt.plot([split, split], [-0.05, 0.25], "k:", linewidth=1)
plt.text(th2s[2] + 0.01, 0.15, "Depth=2", fontsize=13)
plt.title("max_depth=3")

save_fig("tree_regression_plot")
plt.show()
```



In [11]:
```
# extra code – this cell generates and saves Figure 6–6

tree_reg1 = DecisionTreeRegressor(random_state=42)
tree_reg2 = DecisionTreeRegressor(random_state=42, min_samples_leaf=10)
tree_reg1.fit(X_quad, y_quad)
tree_reg2.fit(X_quad, y_quad)

x1 = np.linspace(-0.5, 0.5, 500).reshape(-1, 1)
y_pred1 = tree_reg1.predict(x1)
y_pred2 = tree_reg2.predict(x1)

fig, axes = plt.subplots(ncols=2, figsize=(10, 4), sharey=True)

plt.sca(axes[0])
plt.plot(X_quad, y_quad, "b.")
plt.plot(x1, y_pred1, "r.-", linewidth=2, label=r"$\hat{y}$")
plt.axis([-0.5, 0.5, -0.05, 0.25])
plt.xlabel("$x_1$")
plt.ylabel("$y$", rotation=0)
plt.legend(loc="upper center")
plt.title("No restrictions")

plt.sca(axes[1])
plt.plot(X_quad, y_quad, "b.")
plt.plot(x1, y_pred2, "r.-", linewidth=2, label=r"$\hat{y}$")
plt.axis([-0.5, 0.5, -0.05, 0.25])
plt.xlabel("$x_1$")
plt.title(f"min_samples_leaf={tree_reg2.min_samples_leaf}")

save_fig("tree_regression_regularization_plot")
plt.show()
```


No restrictions
min_samples_leaf=10
$\hat{y}$
y
x_1
x_1
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.4
−0.2
0.0
0.2
0.4