Demo: Decision trees and ensembles

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This is a simple demo notebook that demonstrates a decision tree classifier or an ensemble of decision trees.

Attribution: Parts of this notebook are slightly modified from this tutorial from "Intro to Data Mining".

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

import sklearn
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import BaggingClassifier, RandomForestClassifier, AdaBoostClassifier
```

```
df = pd.read_csv('http://www.cse.msu.edu/~ptan/dmbook/tutorials/tutorial6/vertebrate.csv')
df
```

```
             Name  Warm-blooded  Gives Birth  Aquatic Creature  \
0           human             1            1                 0
1          python             0            0                 0
2          salmon             0            0                 1
3           whale             1            1                 1
4            frog             0            0                 1
5          komodo             0            0                 0
6             bat             1            1                 0
7          pigeon             1            0                 0
8             cat             1            1                 0
9   leopard shark             0            1                 1
10         turtle             0            0                 1
11        penguin             1            0                 1
12      porcupine             1            1                 0
13            eel             0            0                 1
14     salamander             0            0                 1

    Aerial Creature  Has Legs  Hibernates       Class
0                 0         1           0     mammals
1                 0         0           1    reptiles
2                 0         0           0      fishes
3                 0         0           0     mammals
4                 0         1           1  amphibians
5                 0         1           0    reptiles
6                 1         1           1     mammals
7                 1         1           0       birds
8                 0         1           0     mammals
9                 0         0           0      fishes
10                0         1           0    reptiles
11                0         1           0       birds
12                0         1           1     mammals
13                0         0           0      fishes
14                0         1           1  amphibians
```

We'l make it a binary classification problem:

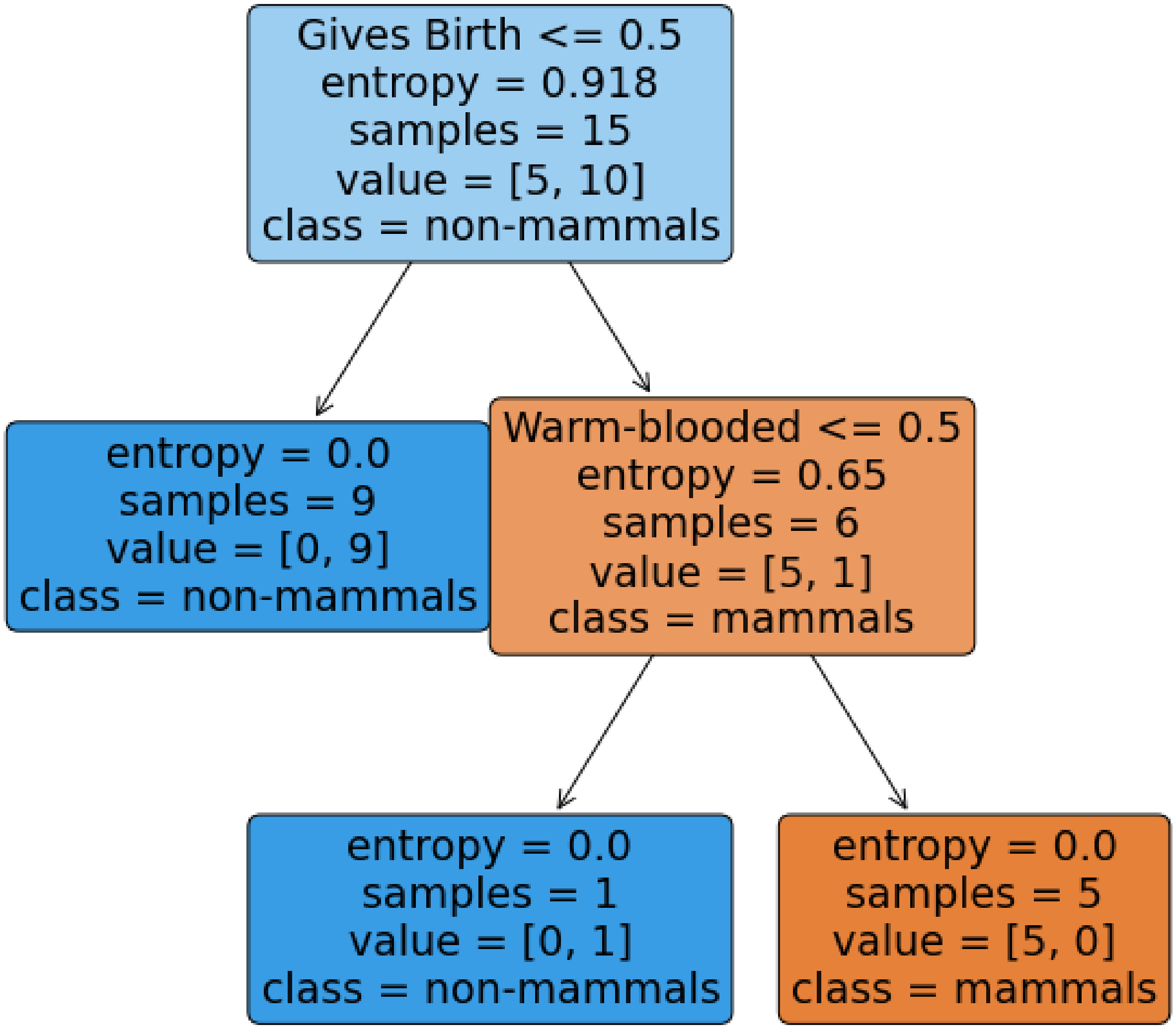
```
df['Class'] = df['Class'].replace(['fishes','birds','amphibians','reptiles'],'non-mammals')
df
```

```
             Name  Warm-blooded  Gives Birth  Aquatic Creature  \
0           human             1            1                 0
1          python             0            0                 0
2          salmon             0            0                 1
3           whale             1            1                 1
4            frog             0            0                 1
5          komodo             0            0                 0
6             bat             1            1                 0
7          pigeon             1            0                 0
8             cat             1            1                 0
9   leopard shark             0            1                 1
10         turtle             0            0                 1
11        penguin             1            0                 1
12      porcupine             1            1                 0
13            eel             0            0                 1
14     salamander             0            0                 1

    Aerial Creature  Has Legs  Hibernates        Class
0                 0         1           0      mammals
1                 0         0           1  non-mammals
2                 0         0           0  non-mammals
3                 0         0           0      mammals
4                 0         1           1  non-mammals
5                 0         1           0  non-mammals
6                 1         1           1      mammals
7                 1         1           0  non-mammals
8                 0         1           0      mammals
9                 0         0           0  non-mammals
10                0         1           0  non-mammals
11                0         1           0  non-mammals
12                0         1           1      mammals
13                0         0           0  non-mammals
14                0         1           1  non-mammals
```

Decision tree

```
y = df['Class']
X = df.drop(['Name','Class'],axis=1)

clf_dt = DecisionTreeClassifier(criterion='entropy')
clf_dt = clf_dt.fit(X, y)
```

```
plt.figure(figsize=(10,10))
sklearn.tree.plot_tree(clf_dt,
                    feature_names = df.columns.drop(['Name', 'Class']),
                    class_names = ["mammals", "non-mammals"],
                    filled=True, rounded=True);
```



Feature importance

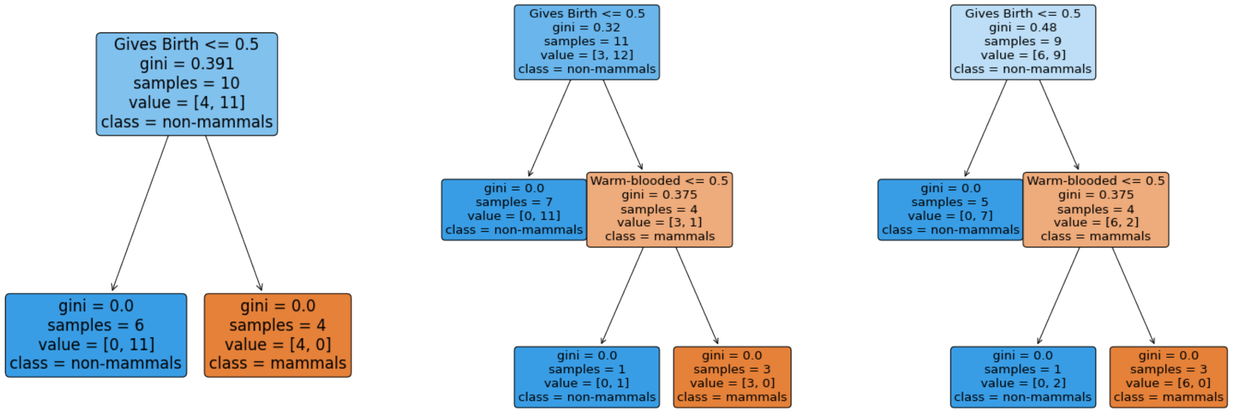
```
df_importance = pd.DataFrame({'feature': df.columns.drop(['Name', 'Class']),
                              'importance': clf_dt.feature_importances_})
df_importance
```

```
            feature  importance
0      Warm-blooded    0.283143
1       Gives Birth    0.716857
2  Aquatic Creature    0.000000
3   Aerial Creature    0.000000
4          Has Legs    0.000000
5        Hibernates    0.000000
```

Bagged tree

```
n_tree = 3
clf_bag = BaggingClassifier(n_estimators=n_tree)
clf_bag = clf_bag.fit(X, y)
```

```
plt.figure(figsize=(n_tree*8, 10))
for idx, clf_t in enumerate(clf_bag.estimators_):
  plt.subplot(1, n_tree,idx+1)
  sklearn.tree.plot_tree(clf_t,
                    feature_names = df.columns.drop(['Name', 'Class']),
                    class_names = ["mammals", "non-mammals"],
                    filled=True, rounded=True)
```



Notice the similarities! The bagged trees are highly correlated.

Let's look at the bootstrap sets each tree was trained on:

```
for samples in clf_bag.estimators_samples_:
  print(df.iloc[samples])
```

```
          Name  Warm-blooded  Gives Birth  Aquatic Creature  Aerial Creature  \
13         eel             0            0                 1                0
6          bat             1            1                 0                1
7       pigeon             1            0                 0                1
14  salamander             0            0                 1                0
14  salamander             0            0                 1                0
12   porcupine             1            1                 0                0
2       salmon             0            0                 1                0
3        whale             1            1                 1                0
2       salmon             0            0                 1                0
10      turtle             0            0                 1                0
11     penguin             1            0                 1                0
10      turtle             0            0                 1                0
13         eel             0            0                 1                0
7       pigeon             1            0                 0                1
8          cat             1            1                 0                0
```

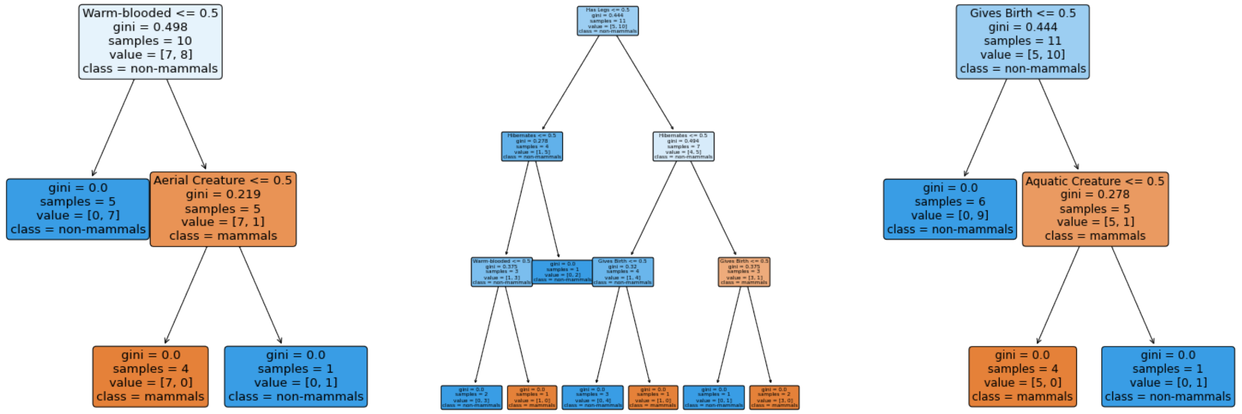
```
    Has Legs  Hibernates        Class
13         0           0  non-mammals
6          1           1      mammals
7          1           0  non-mammals
14         1           1  non-mammals
14         1           1  non-mammals
12         1           1      mammals
2          0           0  non-mammals
3          0           0      mammals
2          0           0  non-mammals
10         1           0  non-mammals
11         1           0  non-mammals
10         1           0  non-mammals
13         0           0  non-mammals
7          1           0  non-mammals
8          1           0      mammals
             Name  Warm-blooded  Gives Birth  Aquatic Creature  \
10         turtle             0            0                 1
0           human             1            1                 0
14     salamander             0            0                 1
3           whale             1            1                 1
9   leopard shark             0            1                 1
11        penguin             1            0                 1
1          python             0            0                 0
2          salmon             0            0                 1
14     salamander             0            0                 1
13            eel             0            0                 1
7          pigeon             1            0                 0
11        penguin             1            0                 1
8             cat             1            1                 0
1          python             0            0                 0
10         turtle             0            0                 1

    Aerial Creature  Has Legs  Hibernates        Class
10                0         1           0  non-mammals
0                 0         1           0      mammals
14                0         1           1  non-mammals
3                 0         0           0      mammals
9                 0         0           0  non-mammals
11                0         1           0  non-mammals
1                 0         0           1  non-mammals
2                 0         0           0  non-mammals
14                0         1           1  non-mammals
13                0         0           0  non-mammals
7                 1         1           0  non-mammals
11                0         1           0  non-mammals
8                 0         1           0      mammals
1                 0         0           1  non-mammals
10                0         1           0  non-mammals
             Name  Warm-blooded  Gives Birth  Aquatic Creature  \
0           human             1            1                 0
13            eel             0            0                 1
9   leopard shark             0            1                 1
```

```
11        penguin             1            0                 1
3           whale             1            1                 1
2          salmon             0            0                 1
5          komodo             0            0                 0
3           whale             1            1                 1
6             bat             1            1                 0
6             bat             1            1                 0
13            eel             0            0                 1
7          pigeon             1            0                 0
11        penguin             1            0                 1
9   leopard shark             0            1                 1
0           human             1            1                 0

    Aerial Creature  Has Legs  Hibernates        Class
0                 0         1           0      mammals
13                0         0           0  non-mammals
9                 0         0           0  non-mammals
11                0         1           0  non-mammals
3                 0         0           0      mammals
2                 0         0           0  non-mammals
5                 0         1           0  non-mammals
3                 0         0           0      mammals
6                 1         1           1      mammals
6                 1         1           1      mammals
13                0         0           0  non-mammals
7                 1         1           0  non-mammals
11                0         1           0  non-mammals
9                 0         0           0  non-mammals
0                 0         1           0      mammals
```

Random forest

```
n_tree = 3
clf_rf = RandomForestClassifier(n_estimators=n_tree, )
clf_rf = clf_rf.fit(X, y)
```

```
plt.figure(figsize=(n_tree*8, 10))
for idx, clf_t in enumerate(clf_rf.estimators_):
  plt.subplot(1, n_tree,idx+1)
  sklearn.tree.plot_tree(clf_t,
                      feature_names = df.columns.drop(['Name', 'Class']),
                      class_names = ["mammals", "non-mammals"],
                      filled=True, rounded=True)
```

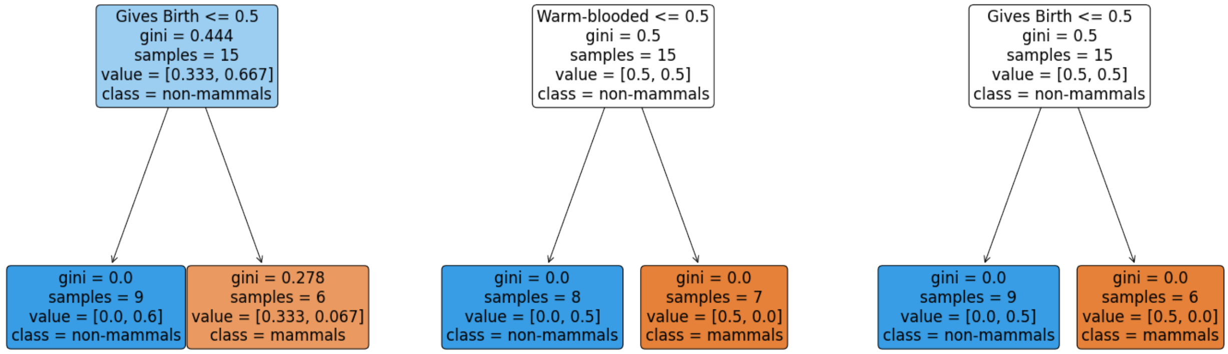


These trees are much less correlated.

AdaBoost

```
n_tree = 3
clf_ab = AdaBoostClassifier(n_estimators=n_tree)
clf_ab = clf_ab.fit(X, y)
```

```
plt.figure(figsize=(n_tree*8, 10))
for idx, clf_t in enumerate(clf_ab.estimators_):
  plt.subplot(1, n_tree,idx+1)
  sklearn.tree.plot_tree(clf_t,
                    feature_names = df.columns.drop(['Name', 'Class']),
                    class_names = ["mammals", "non-mammals"],
                    filled=True, rounded=True)
```



The output will be a weighted average of the predictions of all three trees.

As we add more trees, the ensemble accuracy increases:

```
for p in clf_ab.staged_predict(X):
  print(np.mean(p==y))
```

```
0.9333333333333333
1.0
1.0
```