Lab 5: Introducing Classification

Objectives:

- To gain hands-on experience classifying small dataset
- To implement concepts related to Decision Tree classifier (i.e. Entropy, Information Gain), along with using existing libraries.

In [ ]:
```
# # Run this cell if you use Colab
# from google.colab import drive
# drive.mount('/content/drive')
```

Code it yourself

In [2]:
```
import pandas as pd

# Read the data
df = pd.read_csv('./sources/toy_data.csv')
df
```

Out[2]:

	age	income	student	credit rating	buys computer
0	<=30	high	no	fair	no
1	<=30	high	no	excellent	no
2	31-40	high	no	fair	yes
3	>40	medium	no	fair	yes
4	>40	low	yes	fair	yes
5	>40	low	yes	excellent	no
6	31-40	low	yes	excellent	yes
7	<=30	medium	no	fair	no
8	<=30	low	yes	fair	yes
9	>40	medium	yes	fair	yes
10	<=30	medium	yes	excellent	yes
11	31-40	medium	no	excellent	yes
12	31-40	high	yes	fair	yes
13	>40	medium	no	excellent	no

In [3]:
```
print(df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 14 entries, 0 to 13
Data columns (total 5 columns):
 #   Column          Non-Null Count  Dtype 
---  ------          --------------  ----- 
 0   age             14 non-null     object
 1   income          14 non-null     object
 2   student         14 non-null     object
 3   credit rating   14 non-null     object
 4   buys computer   14 non-null     object
dtypes: object(5)
memory usage: 692.0+ bytes
None
```

TODO: Write functions to compute Gain and Entropy, as discussed in the lecture.

In [4]:
```python
import numpy as np
```

In [5]:
```python
def EntropyCalc(df):
    total_count = df['yes'] + df['no']

    prob_yes = df['yes'] / total_count
    prob_no = df['no'] / total_count

    entropy = 0
    if ( prob_yes > 0 ) :
        entropy -= prob_yes * np.log2(prob_yes)
    if ( prob_no > 0 ) :
        entropy -= prob_no * np.log2(prob_no)

    return entropy
```

In [6]:
```python
def Weighted_EntropyCalc(df , total_target_count):
    total_count = df['yes'] + df['no']

    weighted_ratio = total_count / total_target_count

    entropy = df['Entropy']

    return weighted_ratio * entropy
```

In [7]:
```python
#Target Entropy
target_df = df['buys computer'].value_counts()
target_entropy = EntropyCalc(target_df)
target_entropy
```

Out[7]:
```
np.float64(0.9402859586706311)
```

In [16]:
```python
def compute_information_gain(df, attribute, target, target_entropy, entropy_func, weight
    attr_df = df.groupby(attribute)[target].value_counts().unstack(fill_value=0).reset_i

    for i in range(len(attr_df)):
        attr_df.loc[i, 'Entropy'] = entropy_func(attr_df.loc[i])
        attr_df.loc[i, 'Weighted'] = weighted_entropy_func(attr_df.loc[i], len(df))

    return target_entropy - attr_df['Weighted'].sum()
```

In [17]:
```python
age_ig = compute_information_gain(df, 'age', 'buys computer', target_entropy, EntropyCal
income_ig = compute_information_gain(df, 'income', 'buys computer', target_entropy, Entr
student_ig = compute_information_gain(df, 'student', 'buys computer', target_entropy, En
credit_rating_ig = compute_information_gain(df, 'credit rating', 'buys computer', target
```

```python
print(f'Information Gain of "age" >> {age_ig}')
print(f'Information Gain of "income" >> {income_ig}')
print(f'Information Gain of "student" >> {student_ig}')
print(f'Information Gain of "credit rating" >> {credit_rating_ig}')
```

```
Information Gain of "age" >> 0.24674981977443933
Information Gain of "income" >> 0.02922256565895487
Information Gain of "student" >> 0.15183550136234159
Information Gain of "credit rating" >> 0.04812703040826949
```

Using Libraries

Now that you know how to compute these values by yourselfs, now let's use some libraries.

Steps:

- Split the Data → Divide dataset into training (80%) and testing (20%).
- Train the Model → Fit a Decision Tree using the training data.
- Test the Model → Use the trained model to predict on test data.
- Evaluate Performance → Compare predictions with actual values (e.g., Accuracy Score).

Prepare features and labels.

In [12]:
```python
# Features
features = df.drop('buys computer', axis=1)
features

# Alternatively, you can use this:
# features = df.iloc[:, :-1]
```

Out[12]:

	age	income	student	credit rating
0	<=30	high	no	fair
1	<=30	high	no	excellent
2	31-40	high	no	fair
3	>40	medium	no	fair
4	>40	low	yes	fair
5	>40	low	yes	excellent
6	31-40	low	yes	excellent
7	<=30	medium	no	fair
8	<=30	low	yes	fair
9	>40	medium	yes	fair
10	<=30	medium	yes	excellent
11	31-40	medium	no	excellent
12	31-40	high	yes	fair
13	>40	medium	no	excellent

In [13]:
```
# Labels (or Target)
labels = df['buys computer']
labels

# # Alternatively, you can use this:
# labels = df.iloc[:, [-1]]
```

Out[13]:
```
0      no
1      no
2     yes
3     yes
4     yes
5      no
6     yes
7      no
8     yes
9     yes
10    yes
11    yes
12    yes
13     no
Name: buys computer, dtype: object
```

In [14]:
```
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier, plot_tree
```

In [15]:
```
# 1. Load the dataset
X = features.values  # Features
y = labels.values  # Target labels

# 2. Split the dataset into training (80%) and testing (20%)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42

# 3. Create and train a Decision Tree model with entropy criterion
clf = DecisionTreeClassifier(criterion='entropy', max_depth=3, random_state=42)
clf.fit(X_train, y_train)
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[15], line 10
      8 # 3. Create and train a Decision Tree model with entropy criterion
      9 clf = DecisionTreeClassifier(criterion='entropy', max_depth=3, random_state=42)
---> 10 clf.fit(X_train, y_train)

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\base.py:1389, in _fit_context.<locals>.decorator.<locals>.wrapper(estimator, *args, *
*kwargs)
   1382     estimator._validate_params()
   1384 with config_context(
   1385     skip_parameter_validation=(
   1386         prefer_skip_nested_validation or global_skip_validation
   1387     )
   1388 ):
-> 1389     return fit_method(estimator, *args, **kwargs)

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\tree\_classes.py:1024, in DecisionTreeClassifier.fit(self, X, y, sample_weight, check
_input)
    993 @_fit_context(prefer_skip_nested_validation=True)
    994 def fit(self, X, y, sample_weight=None, check_input=True):
    995     """Build a decision tree classifier from the training set (X, y).
    996 
    997     Parameters
   (...)
   1021         Fitted estimator.
   1022     """
-> 1024     super()._fit(
   1025         X,
   1026         y,
   1027         sample_weight=sample_weight,
   1028         check_input=check_input,
   1029     )
   1030     return self

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\tree\_classes.py:252, in BaseDecisionTree._fit(self, X, y, sample_weight, check_inpu
t, missing_values_in_feature_mask)
    248 check_X_params = dict(
    249     dtype=DTYPE, accept_sparse="csc", ensure_all_finite=False
    250 )
    251 check_y_params = dict(ensure_2d=False, dtype=None)
--> 252 X, y = validate_data(
    253     self, X, y, validate_separately=(check_X_params, check_y_params)
    254 )
    256 missing_values_in_feature_mask = (
    257     self._compute_missing_values_in_feature_mask(X)
    258 )
    259 if issparse(X):

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\utils\validation.py:2956, in validate_data(_estimator, X, y, reset, validate_separate
ly, skip_check_array, **check_params)
   2954 if "estimator" not in check_X_params:
   2955     check_X_params = {**default_check_params, **check_X_params}
-> 2956 X = check_array(X, input_name="X", **check_X_params)
   2957 if "estimator" not in check_y_params:
   2958     check_y_params = {**default_check_params, **check_y_params}

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\utils\validation.py:1055, in check_array(array, accept_sparse, accept_large_sparse, d
```

```
type, order, copy, force_writeable, force_all_finite, ensure_all_finite, ensure_non_negat
ive, ensure_2d, allow_nd, ensure_min_samples, ensure_min_features, estimator, input_name)
   1053         array = xp.astype(array, dtype, copy=False)
   1054     else:
-> 1055         array = _asarray_with_order(array, order=order, dtype=dtype, xp=xp)
   1056 except ComplexWarning as complex_warning:
   1057     raise ValueError(
   1058         "Complex data not supported\n{}\n".format(array)
   1059     ) from complex_warning

File c:\Users\Feen_Phoorin\AppData\Local\Programs\Python\Python313\Lib\site-packages\skle
arn\utils\_array_api.py:839, in _asarray_with_order(array, dtype, order, copy, xp, devic
e)
    837     array = numpy.array(array, order=order, dtype=dtype)
    838 else:
--> 839     array = numpy.asarray(array, order=order, dtype=dtype)
    841 # At this point array is a NumPy ndarray. We convert it to an array
    842 # container that is consistent with the input's namespace.
    843 return xp.asarray(array)

ValueError: could not convert string to float: '31-40'
```

There's an error:

ValueError: could not convert string to float: '31-40'

In [18]:

```
from sklearn.preprocessing import LabelEncoder

# Initialize LabelEncoder
label_encoder = LabelEncoder()

# Apply Label Encoding for all categorical columns
df['age'] = label_encoder.fit_transform(df['age'])
df['income'] = label_encoder.fit_transform(df['income'])
df['student'] = label_encoder.fit_transform(df['student'])
df['credit rating'] = label_encoder.fit_transform(df['credit rating'])
df['buys computer'] = label_encoder.fit_transform(df['buys computer'])

# Display the encoded DataFrame
print(df)
```

```
    age  income  student  credit rating  buys computer
0     1       0        0              1              0
1     1       0        0              0              0
2     0       0        0              1              1
3     2       2        0              1              1
4     2       1        1              1              1
5     2       1        1              0              0
6     0       1        1              0              1
7     1       2        0              1              0
8     1       1        1              1              1
9     2       2        1              1              1
10    1       2        1              0              1
11    0       2        0              0              1
12    0       0        1              1              1
13    2       2        0              0              0
```

Let's check out an updated dataframe.

In [19]:

```
df
```

Out[19]:

	age	income	student	credit rating	buys computer
0	1	0	0	1	0
1	1	0	0	0	0
2	0	0	0	1	1
3	2	2	0	1	1
4	2	1	1	1	1
5	2	1	1	0	0
6	0	1	1	0	1
7	1	2	0	1	0
8	1	1	1	1	1
9	2	2	1	1	1
10	1	2	1	0	1
11	0	2	0	0	1
12	0	0	1	1	1
13	2	2	0	0	0

In [20]:
```
X = df.drop('buys computer', axis=1)  # Features
y = df['buys computer']  # Target
```

Let's continue where we left off!

In [21]:
```
# 2. Split the dataset into training (80%) and testing (20%)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42

# 3. Create and train a Decision Tree model with entropy criterion
clf = DecisionTreeClassifier(criterion='entropy', max_depth=3, random_state=42)
clf.fit(X_train, y_train)
```

Out[21]:
```
DecisionTreeClassifier
DecisionTreeClassifier(criterion='entropy', max_depth=3, random_state=42)
```

In [22]:
```
print(X_train.shape)
print(X_test.shape)
```

```
(11, 4)
(3, 4)
```

Now we're going build the Decision Tree Classifier

In [23]:
```
from sklearn.tree import DecisionTreeClassifier

# Initialize the Decision Tree classifier
clf = DecisionTreeClassifier(criterion='entropy', random_state=42)  # Using 'entropy' as

# Train the model
clf.fit(X_train, y_train)
```

```
# Predict on the test set
y_pred = clf.predict(X_test)
```

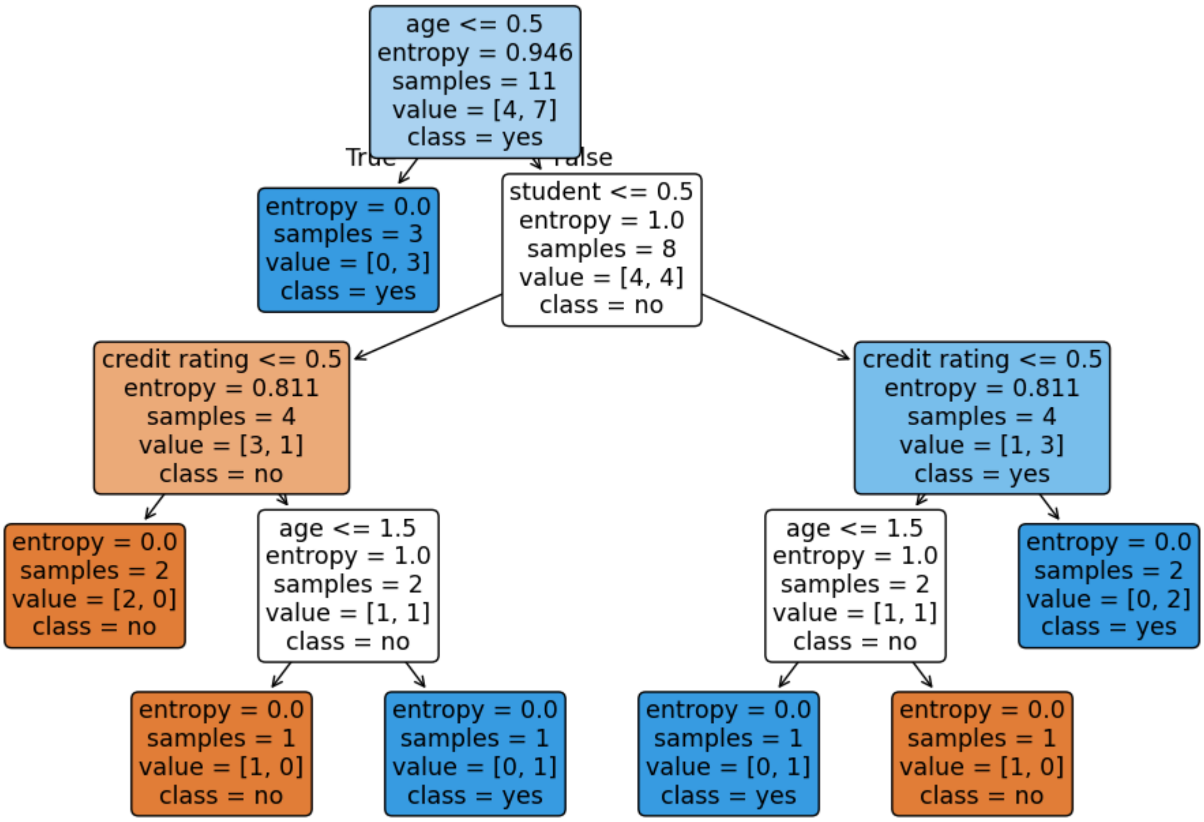
And evaluate our model.

```
In [24]: from sklearn.metrics import accuracy_score, classification_report, confusion_matrix

# Calculate accuracy
accuracy = accuracy_score(y_test, y_pred)
print(f"Accuracy: {accuracy:.2f}")

# Classification report
print("Classification Report:")
print(classification_report(y_test, y_pred))

# Confusion Matrix
print("Confusion Matrix:")
print(confusion_matrix(y_test, y_pred))
```

```
Accuracy: 1.00
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00         1
           1       1.00      1.00      1.00         2

    accuracy                           1.00         3
   macro avg       1.00      1.00      1.00         3
weighted avg       1.00      1.00      1.00         3

Confusion Matrix:
[[1 0]
 [0 2]]
```

And visualize our tree!

```
In [25]: import matplotlib.pyplot as plt
from sklearn.tree import plot_tree

# Plot the decision tree
plt.figure(figsize=(12, 8))
plot_tree(clf, filled=True, feature_names=X.columns, class_names=['no', 'yes'], rounded=
plt.show()
```

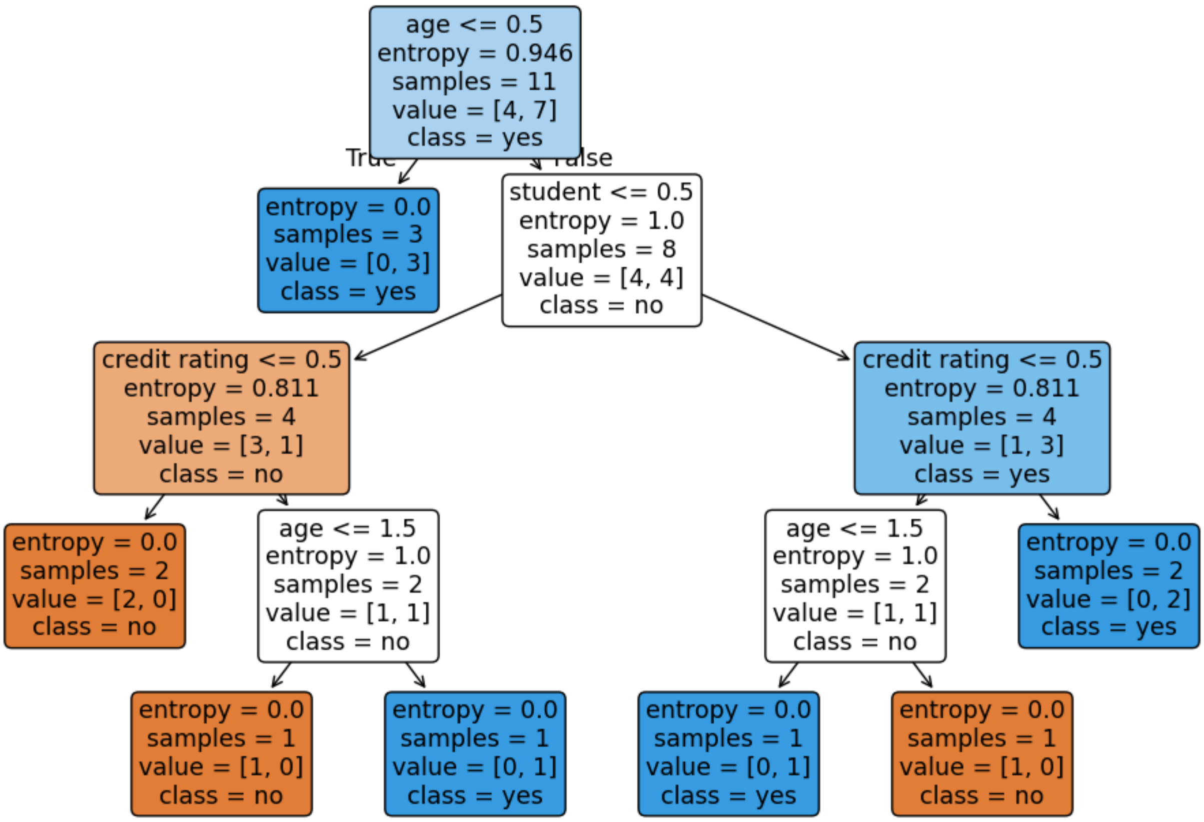


Put them all together.

In [26]:
```
import pandas as pd
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score, classification_report, confusion_matrix
import matplotlib.pyplot as plt
from sklearn.tree import plot_tree

# data
data = pd.read_csv('sources/toy_data.csv')

df = pd.DataFrame(data)

# Encode categorical columns using LabelEncoder
label_encoder = LabelEncoder()
df['age'] = label_encoder.fit_transform(df['age'])
df['income'] = label_encoder.fit_transform(df['income'])
df['student'] = label_encoder.fit_transform(df['student'])
df['credit rating'] = label_encoder.fit_transform(df['credit rating'])
df['buys computer'] = label_encoder.fit_transform(df['buys computer'])

# Separate features (X) and target (y)
X = df.drop('buys computer', axis=1)
y = df['buys computer']

# Split the dataset into training and test sets (80% train, 20% test)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42

# Initialize the Decision Tree classifier
clf = DecisionTreeClassifier(criterion='entropy', random_state=42)

# Train the model
clf.fit(X_train, y_train)
```

```python
# Predict on the test set
y_pred = clf.predict(X_test)

# Calculate accuracy
accuracy = accuracy_score(y_test, y_pred)
print(f"Accuracy: {accuracy:.2f}")

# Classification report
print("Classification Report:")
print(classification_report(y_test, y_pred))

# Confusion Matrix
print("Confusion Matrix:")
print(confusion_matrix(y_test, y_pred))

# Plot the decision tree
plt.figure(figsize=(12, 8))
plot_tree(clf, filled=True, feature_names=X.columns, class_names=['no', 'yes'], rounded=
plt.show()
```

```
Accuracy: 1.00
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00         1
           1       1.00      1.00      1.00         2

    accuracy                           1.00         3
   macro avg       1.00      1.00      1.00         3
weighted avg       1.00      1.00      1.00         3

Confusion Matrix:
[[1 0]
 [0 2]]
```



Is the output tree the same as what you calculated yourself? Explain in your own words why they are the same or different.

Ans: The entropy and information gain are not the same since the model use only 80% of the dataset (11 samples), while hand calculated use 100 % of the dataset (14 samples)

Another example, another dataset -- Iris

In [27]:
```
from sklearn.datasets import load_iris

# 1. Load the Iris dataset
iris = load_iris()
X = iris.data  # Features
y = iris.target  # Target labels

# 2. Split the dataset into training (80%) and testing (20%)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42

# 3. Create and train a Decision Tree model with entropy criterion
clf = DecisionTreeClassifier(criterion='entropy', max_depth=3, random_state=42)
clf.fit(X_train, y_train)

# 4. Make predictions on the test set
y_pred = clf.predict(X_test)

# 5. Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
print(f"Model Accuracy: {accuracy:.2f}")

# 6. Visualize the Decision Tree
plt.figure(figsize=(10, 6))
plot_tree(clf, filled=True, feature_names=iris.feature_names, class_names=iris.target_na
plt.show()
```

```
Model Accuracy: 1.00
```