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Avinash Navlani
December 28th, 2018

PYTHON

Decision Tree Classification in Python

In this tutorial, learn Decision Tree Classification, attribute selection measures, and how to build and optimize Decision Tree Classifier using Python Scikit-learn package.



As a marketing manager, you want a set of customers who are most likely to purchase your product. This is how you can save your marketing budget by finding your audience. As a loan manager, you need to identify risky loan applications to achieve a lower loan default rate. This process of classifying customers into a group of potential and non-potential customers or safe or risky loan applications is known as a classification problem. Classification is a two-step process, learning step and prediction step. In the learning step, the model is developed based on given training data. In the prediction step, the model is used to predict the response for given data. Decision Tree is one of the easiest and popular classification algorithms to understand and interpret. It can be utilized for both classification and regression kind of problem.

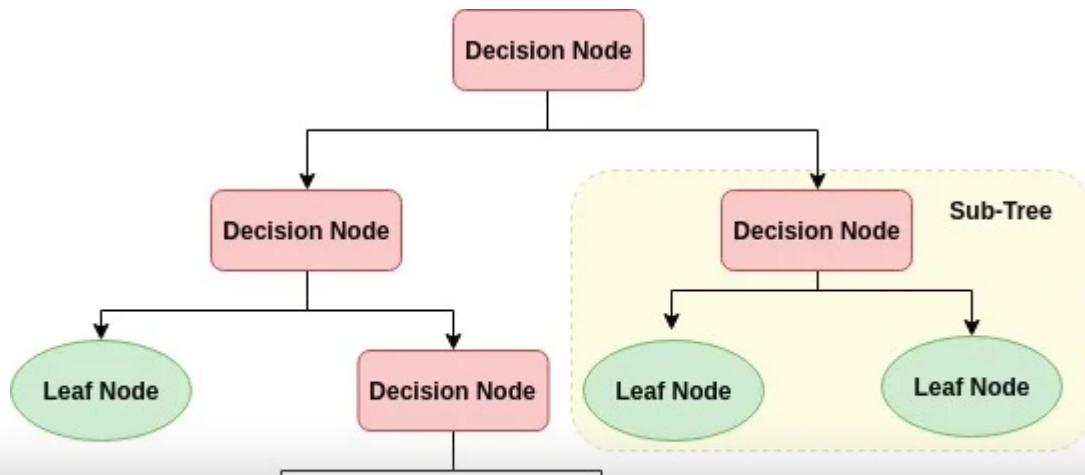
In this tutorial, you are going to cover the following topics:

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- Attribute Selection Measures
 - Information Gain
 - Gain Ratio
 - Gini index
- Optimizing Decision Tree Performance
- Classifier Building in Scikit-learn
- Pros and Cons
- Conclusion

Decision Tree Algorithm

A decision tree is a flowchart-like tree structure where an internal node represents feature(or attribute), the branch represents a decision rule, and each leaf node represents the outcome. The topmost node in a decision tree is known as the root node. It learns to partition on the basis of the attribute value. It partitions the tree in recursively manner call recursive partitioning. This flowchart-like structure helps you in decision making. It's visualization like a flowchart diagram which easily mimics the human level thinking. That is why decision trees are easy to understand and interpret.



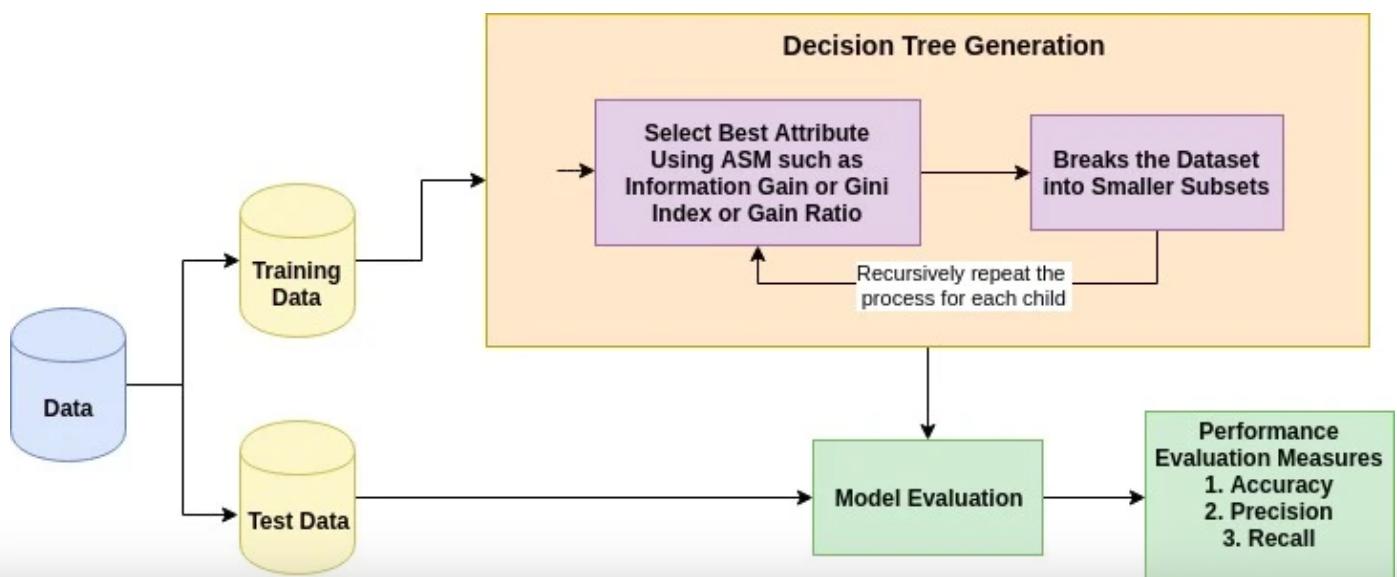
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time is faster compared to the neural network algorithm. The time complexity of decision trees is a function of the number of records and number of attributes in the given data. The decision tree is a distribution-free or non-parametric method, which does not depend upon probability distribution assumptions. Decision trees can handle high dimensional data with good accuracy.

How does the Decision Tree algorithm work?

The basic idea behind any decision tree algorithm is as follows:

1. Select the best attribute using Attribute Selection Measures(ASM) to split the records.
2. Make that attribute a decision node and breaks the dataset into smaller subsets.
3. Starts tree building by repeating this process recursively for each child until one of the condition will match:
 - All the tuples belong to the same attribute value.
 - There are no more remaining attributes.
 - There are no more instances.



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determine breakpoints for tuples on a given node. ASM provides a rank to each feature(or attribute) by explaining the given dataset. Best score attribute will be selected as a splitting attribute (**Source**). In the case of a continuous-valued attribute, split points for branches also need to define. Most popular selection measures are Information Gain, Gain Ratio, and Gini Index.

Information Gain

Shannon invented the concept of entropy, which measures the impurity of the input set. In physics and mathematics, entropy referred as the randomness or the impurity in the system. In information theory, it refers to the impurity in a group of examples. Information gain is the decrease in entropy. Information gain computes the difference between entropy before split and average entropy after split of the dataset based on given attribute values. ID3 (Iterative Dichotomiser) decision tree algorithm uses information gain.

$$\text{Info}(D) = - \sum_{i=1}^m p_i \log_2 p_i$$

Where, P_i is the probability that an arbitrary tuple in D belongs to class C_i .

$$\text{Info}_A(D) = \sum_{j=1}^V \frac{|D_j|}{|D|} \times \text{Info}(D_j)$$

$$\text{Gain}(A) = \text{Info}(D) - \text{Info}_A(D)$$

Where,

- $\text{Info}(D)$ is the average amount of information needed to identify the class label of a tuple in D .
- $|D_j|/|D|$ acts as the weight of the j th partition.

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Gain Ratio

Information gain is biased for the attribute with many outcomes. It means it prefers the attribute with a large number of distinct values. For instance, consider an attribute with a unique identifier such as customer_ID has zero info(D) because of pure partition. This maximizes the information gain and creates useless partitioning.

C4.5, an improvement of ID3, uses an extension to information gain known as the gain ratio. Gain ratio handles the issue of bias by normalizing the information gain using Split Info. Java implementation of the C4.5 algorithm is known as J48, which is available in WEKA data mining tool.

$$\text{SplitInfo}_A(D) = - \sum_{j=1}^v \frac{|D_j|}{|D|} \times \log_2 \left(\frac{|D_j|}{|D|} \right)$$

Where,

- $|D_j|/|D|$ acts as the weight of the jth partition.
- v is the number of discrete values in attribute A.

The gain ratio can be defined as

$$\text{GainRatio}(A) = \frac{\text{Gain}(A)}{\text{SplitInfo}_A(D)}$$

The attribute with the highest gain ratio is chosen as the splitting attribute (Source).

Gini index

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Where, p_i is the probability that a tuple in D belongs to class C_i .

The Gini Index considers a binary split for each attribute. You can compute a weighted sum of the impurity of each partition. If a binary split on attribute A partitions data D into D₁ and D₂, the Gini index of D is:

$$\text{Gini}_A(D) = \frac{|D_1|}{|D|} \text{Gini}(D_1) + \frac{|D_2|}{|D|} \text{Gini}(D_2)$$

In case of a discrete-valued attribute, the subset that gives the minimum gini index for that chosen is selected as a splitting attribute. In the case of continuous-valued attributes, the strategy is to select each pair of adjacent values as a possible split-point and point with smaller gini index chosen as the splitting point.

$$\Delta \text{Gini}(A) = \text{Gini}(D) - \text{Gini}_A(D).$$

The attribute with minimum Gini index is chosen as the splitting attribute.

Decision Tree Classifier Building in Scikit-learn

Importing Required Libraries

Let's first load the required libraries.

```
# Load libraries
import pandas as pd
from sklearn.tree import DecisionTreeClassifier # Import Decision Tree Classifier
from sklearn.model_selection import train_test_split # Import train_test_split function
from sklearn import metrics #Import scikit-learn metrics module for accuracy calculation
```

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```
col_names = ['pregnant', 'glucose', 'bp', 'skin', 'insulin', 'bmi', 'pedigree', 'age', 'label']
# load dataset
pima = pd.read_csv("pima-indians-diabetes.csv", header=None, names=col_names)
```

pima.head()

	pregnant	glucose	bp	skin	insulin	bmi	pedigree	age	label
0	6	148	72	35	0	33.6	0.627	50	1
1	1	85	66	29	0	26.6	0.351	31	0
2	8	183	64	0	0	23.3	0.672	32	1
3	1	89	66	23	94	28.1	0.167	21	0
4	0	137	40	35	168	43.1	2.288	33	1

Feature Selection

Here, you need to divide given columns into two types of variables dependent(or target variable) and independent variable(or feature variables).

```
#split dataset in features and target variable
feature_cols = ['pregnant', 'insulin', 'bmi', 'age','glucose','bp','pedigree']
X = pima[feature_cols] # Features
y = pima.label # Target variable
```

Splitting Data

To understand model performance, dividing the dataset into a training set and a test set is a

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```
# Split dataset into training set and test set
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=1) # 70%
```

Building Decision Tree Model

Let's create a Decision Tree Model using Scikit-learn.

```
# Create Decision Tree classifier object
clf = DecisionTreeClassifier()

# Train Decision Tree Classifier
clf = clf.fit(X_train,y_train)

#Predict the response for test dataset
y_pred = clf.predict(X_test)
```

Evaluating Model

Let's estimate, how accurately the classifier or model can predict the type of cultivars.

Accuracy can be computed by comparing actual test set values and predicted values.

```
# Model Accuracy, how often is the classifier correct?
print("Accuracy:",metrics.accuracy_score(y_test, y_pred))
```

Accuracy: 0.6753246753246753

Well, you got a classification rate of 67.53%, considered as good accuracy. You can improve this accuracy by tuning the parameters in the Decision Tree Algorithm.

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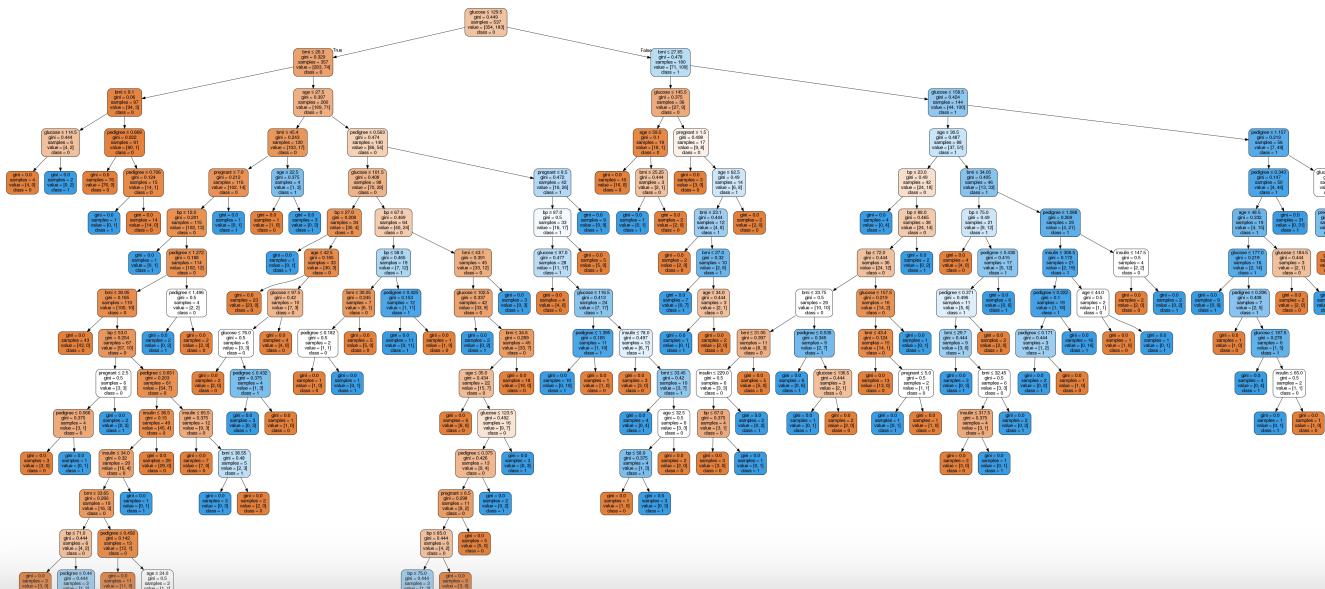
```
pip install graphviz
```

```
pip install pydotplus
```

`export_graphviz` function converts decision tree classifier into dot file and `pydotplus` convert this dot file to png or displayable form on Jupyter.

```
from sklearn.tree import export_graphviz
from sklearn.externals.six import StringIO
from IPython.display import Image
import pydotplus

dot_data = StringIO()
export_graphviz(clf, out_file=dot_data,
                filled=True, rounded=True,
                special_characters=True, feature_names = feature_cols, class_names=['0', '1'])
graph = pydotplus.graph_from_dot_data(dot_data.getvalue())
graph.write_png('diabetes.png')
Image(graph.create_png())
```



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when all of its records belong to the same class, such nodes known as the leaf node.

Here, the resultant tree is unpruned. This unpruned tree is unexplainable and not easy to understand. In the next section, let's optimize it by pruning.

Optimizing Decision Tree Performance

- **criterion : optional (default="gini") or Choose attribute selection measure:** This parameter allows us to use the different-different attribute selection measure. Supported criteria are “gini” for the Gini index and “entropy” for the information gain.
- **splitter : string, optional (default="best") or Split Strategy:** This parameter allows us to choose the split strategy. Supported strategies are “best” to choose the best split and “random” to choose the best random split.
- **max_depth : int or None, optional (default=None) or Maximum Depth of a Tree:** The maximum depth of the tree. If None, then nodes are expanded until all the leaves contain less than min_samples_split samples. The higher value of maximum depth causes overfitting, and a lower value causes underfitting ([Source](#)).

In Scikit-learn, optimization of decision tree classifier performed by only pre-pruning. Maximum depth of the tree can be used as a control variable for pre-pruning. In the following the example, you can plot a decision tree on the same data with max_depth=3. Other than pre-pruning parameters, You can also try other attribute selection measure such as entropy.

```
# Create Decision Tree classifier object
clf = DecisionTreeClassifier(criterion="entropy", max_depth=3)

# Train Decision Tree Classifier
clf = clf.fit(X_train,y_train)
```

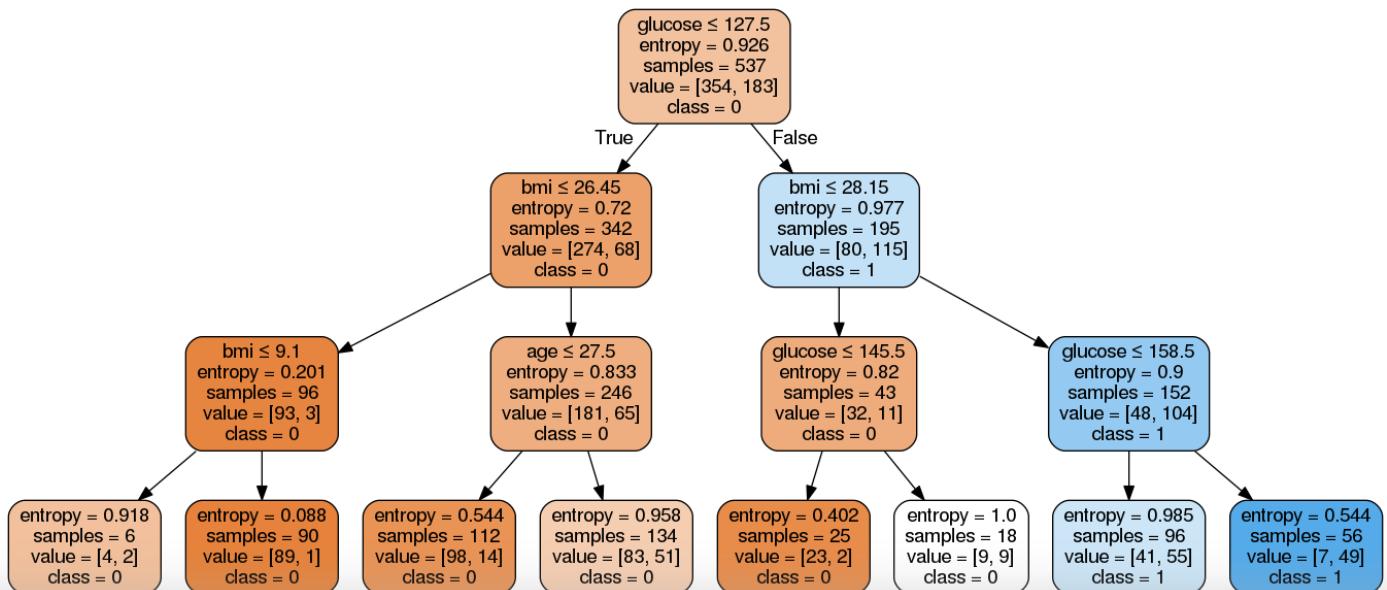
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Accuracy: 0.7705627705627706

Well, the classification rate increased to 77.05%, which is better accuracy than the previous model.

Visualizing Decision Trees

```
from sklearn.externals.six import StringIO
from IPython.display import Image
from sklearn.tree import export_graphviz
import pydotplus
dot_data = StringIO()
export_graphviz(clf, out_file=dot_data,
                filled=True, rounded=True,
                special_characters=True, feature_names = feature_cols,class_names=['0','1'])
graph = pydotplus.graph_from_dot_data(dot_data.getvalue())
graph.write_png('diabetes.png')
Image(graph.create_png())
```



Want to leave a comment?

- Decision trees are easy to interpret and visualize.
- It can easily capture Non-linear patterns.
- It requires fewer data preprocessing from the user, for example, there is no need to normalize columns.
- It can be used for feature engineering such as predicting missing values, suitable for variable selection.
- The decision tree has no assumptions about distribution because of the non-parametric nature of the algorithm. ([Source](#))

Cons

- Sensitive to noisy data. It can overfit noisy data.
- The small variation(or variance) in data can result in the different decision tree. This can be reduced by bagging and boosting algorithms.
- Decision trees are biased with imbalance dataset, so it is recommended that balance out the dataset before creating the decision tree.

Conclusion

Congratulations, you have made it to the end of this tutorial!

In this tutorial, you covered a lot of details about Decision Tree; It's working, attribute selection measures such as Information Gain, Gain Ratio, and Gini Index, decision tree model building, visualization and evaluation on diabetes dataset using Python Scikit-learn package. Also, discussed its pros, cons, and optimizing Decision Tree performance using parameter tuning.

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COMMENTS

Dendani Bilal

16/02/2019 12:49 AM

Thank you Avinash.

It was very helpful however I got the following error after I run the code until `y_pred = clf.predict(X_test)`. The following is the error :

`ValueError: could not convert string to float: 'DiabetesPedigreeFunction'`

▲ 14 ← REPLY

Avinash Navlani

18/03/2019 08:08 AM

May be your data has null values. Please check your dataset.

▲ 6 ← REPLY

Zahid Parvez

18/03/2019 06:35 PM

You need to factorize your categorical data, the model cant deal with non-numeric data.

Have a look at:

- <https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.LabelEncoder.html>
- <https://stackoverflow.com/questions/38108832/passing-categorical-data-to-sklearn-decision-tree>

Want to leave a comment?

I hat still does not solve the problem. The tutorial is buggy ...

▲ 3

Emmanuel Davidson

28/07/2019 10:05 AM

delete the first row of the dataframe

```
pima = pd.read_csv("diabetes.csv", header=None, names=col_names)  
pima = pima.iloc[1:]
```

▲ 4

Virendra Mishra

11/04/2019 04:02 AM

i got the same error and i used the below script before train the model.

```
LE = preprocessing.LabelEncoder()  
  
data = yourdatasetname.apply(LE .fit_transform)
```

▲ 1 ↗ REPLY

Colin Contreary

19/04/2019 08:06 PM

If you downloaded the dataset from Kaggle, it comes with a header row. Try replacing it as follows:

```
<code>  
  
col_names = ['pregnant', 'glucose', 'bp', 'skin', 'insulin', 'bmi', 'pedigree', 'age', 'label']  
  
pima = pd.read_csv("diabetes.csv")  
  
pima.columns = col_names  
  
</code>
```

That worked for me!

▲ 7 ↗ REPLY

Ami Joy

24/04/2019 10:35 AM

Want to leave a comment?

thanks a lot it worked :)

▲ 1

Luis Alfonso Gómez Zúñiga

22/12/2019 11:16 PM

This work for me!! Thanks

▲ 1

Hamid K Hamedani

03/01/2020 02:21 PM

Great! worked for me as well. Thanks, Could you let us know what was the problem and what your code does?

▲ 1

GANESH PANDIT

05/01/2020 01:52 AM

i'm getting error so please can you send me the complete code

so that i can check where i did mistake

▲ 1

Avinash Navlani

20/04/2019 10:03 PM

Colin Contreary is right. May be your dataset has columns in it. if you see the data none of the column is String. So need to apply label encoding.

▲ 1 ↗ REPLY

sahala salim

14/06/2019 02:50 AM

`ValueError: could not convert string to float: 'Insulin'`

Want to leave a comment?

```
pima = pd.read_csv("pima-indians-diabetes.csv", header=None, names=col_names)
```

with

```
pima = pd.read_csv("diabetes.csv", header=0, names=col_names)
```

▲ 3 ↗ REPLY

kiran kumari

08/04/2019 03:02 PM

Thanks a lot Sir! But I got an error :

```
InvocationException: GraphViz's executables not found
```

Can you please help me out?

▲ 4 ↗ REPLY

Virendra Mishra

11/04/2019 04:06 AM

you need to install Graphviz, instal pydotplus and setup environment variable. after doing these three step you will see the tree.let me know if you still see error

▲ 5 ↗ REPLY

Colin Contryreary

19/04/2019 07:48 PM

I had the same problem of "GraphViz's executables not found." I'm using Windows 10. What worked for me was going into the Environment Variables and adding the graphviz folder to my PATH settings.

You can search "Environment variables" in the search bar of your desktop, or find them manually under Control Panel > System > Advanced System Settings.

Click into Environment Variables and then click Path under the User Variables box.

On my computer, the graphviz folder is stored in
C:\Users\Colin\Anaconda3\Library\bin\graphviz

Want to leave a comment?

If not, you can try reading this StackOverflow post in case something else works:
<https://stackoverflow.com/questions/18438997/why-is-pydot-unable-to-find-graphviz-executables-in-windows-8>

▲ 3 ↗ REPLY

Avinash Navlani

20/04/2019 09:56 PM

Graphviz installation is tricky thing. Initially I also got problem in that. Follow the [Colin Contrary's](#) Solution.

▲ 1

LIA FAROKHAAH

29/08/2019 01:08 AM

Change path and it work

InvocationException: GraphViz's executables not found

▲ 2

Michael Bhekumuzi Maima

02/10/2019 12:59 AM

Hi Colin,

You can visualize the decision without creating a PATH, check the code below:

```
decisionGraph = Source(tree.export_graphviz(clf,  
                                         out_file = None,  
                                         feature_names = features,  
                                         class_names = ['0', '1'],  
                                         filled = True,  
                                         rounded = True))
```

Want to leave a comment?

I tried the update Environment variables fixed.. I now get a new error:

```
-----  
NameError                                     Traceback (most recent call last)  
<ipython-input-1-e2816f0728af> in <module>  
      5  
      6 dot_data = StringIO()  
----> 7 export_graphviz(clf, out_file=dot_data,  
      8             filled=True, rounded=True,  
      9             special_characters=True, feature_names = feature_cols, clas
```

NameError: name 'clf' is not defined

[]:

▲ 1

Jennifer Jenkins

24/08/2019 05:09 PM

I solved this problem by going to Terminal and typing

conda install graphviz. I am using Anaconda on a Mac.

▲ 1 ← REPLY

ANURAG NAGAR

06/05/2019 10:27 AM

I am getting the following error

could not convert string to float:

Want to leave a comment?

▲ 1 REPLY

David Galli

07/05/2019 04:49 AM

State machines are the basics of computer science. It's kind of funny to suggest this as an extra reading material... on the other hand, it's also funny to think that they are a good way to deal with decision trees. Since, if you ever took an [uk essay writing](#) automata class, you'd know that state machines are limited in that they don't have any "memory", which means that you can only describe regular languages using this formalism.

▲ 1 REPLY

Kevin Ochieng

31/05/2019 12:45 AM

DataCamp kindly try to be clear and procedural like other platforms like towardsdatascience and medium.com ,every time i follow your tutorials errors become my friends and you get other steps skipped without informing the learnings

▲ 1 REPLY

Suraj Meena

28/06/2019 12:05 PM

Do we need to encode categorical variables or not for decision tree to work ?

▲ 1 REPLY

Suraj Meena

28/06/2019 12:06 PM

Also, if we do not need to encode categorical variables then how will decision tree know that particular columns in our dataset are categorical ?

▲ 1 REPLY

javid iqbal

30/07/2019 05:48 AM

Dear Avinash

Want to leave a comment?

-----> 9

```
special_characters=True,feature_names = feature_cols,class_nam
```



▲ 1 ↗ REPLY

AJ Ferrara

31/07/2019 06:45 PM

great tutorial. was able to apply on my own data. can you please reccomend some tips on balancing a dataset with only 1% = 1? I'd like to keep all 1%, about 800 tecords. Thanks

▲ 2 ↗ REPLY

Avinash Navlani

22/08/2019 09:12 PM

You can try oversampling and under-sampling.

▲ 1 ↗ REPLY

Smruti Vyavahare

14/08/2019 02:03 AM

in this decision tree red faint red grey dark nodes are there. how color changed in code where mentioned.please tell in detail

▲ 1 ↗ REPLY

Prateek Ramsinghani

15/08/2019 03:15 PM

Thanks for the tutorial, I was able to use the same code and develop the tree but the problem is, I had all categorical variables and converted them using label encoder while developing the tree it shows values in decimals (can be considered similar to pregnant > 1.5 and < 1.5 in the above example) which does not make any sense, can someone please suggest a way in which I can keep the values as whole numbers.

▲ 1 ↗ REPLY

Want to leave a comment?

- I tried to increase my class_names,

```
class_names=['true','false','something else']
```

- I tried to label my feature_names with numbers,

```
feature_names=['1', '2', '3', '4', '5', '6', '7', '8', '9', '10', '11', '12', '13', '14'],
```

but they didn't solve the problem.

I have 14 feature columns, 1 target column and 15 columns in total.

Does anyone knows how can I fix it?

▲ 1 ↗ REPLY

Sai Prasanna

17/08/2019 08:58 AM

way to calculate entropy without using decision tree alogarithm

▲ 2 ↗ REPLY

Avinash Navlani

22/08/2019 09:09 PM

Yes, using formula. you can calculate for small dataset and for large dataset you need to write program.

▲ 1 ↗ REPLY

Veer Pratap Singh

25/08/2019 01:34 AM

very helpfull

Want to leave a comment?

LIA FAROKHAAH

29/08/2019 06:34 AM

Great tutorial, thank you for sharing..

▲ 2 [REPLY](#)

pcckee

01/09/2019 12:56 PM

I've been struggling with this concept for few weeks. This article really helps!

▲ 2 [REPLY](#)

Ernesto Ernane

03/09/2019 06:58 AM

obrigado foi útil

▲ 1 [REPLY](#)

87 H

09/09/2019 03:21 PM

It is very helpful to understand the decision tree. Do you have any recommendation how to apply the formula to practical questions, that would be helpful to understand the formula well. Thanks.

▲ 1 [REPLY](#)

aliyu abdul

23/09/2019 06:39 AM

Quick question.

Please how can the decision tree be used for image dataset

▲ 1 [REPLY](#)

MD NAZMUL ISLAM

01/10/2019 01:09 PM

Great writing :)

[Want to leave a comment?](#)

For `accuracy_score()` function, is it necessary to have same length of `y_test` and `y_pred`?

▲ 1 ↗ REPLY

Brent Niland

06/10/2019 08:20 PM

Hi Avinash, thank you for this article. Where do I place the `diabetes.csv` file after downloading so that python can read it?

▲ 1 ↗ REPLY

Brent Niland

08/10/2019 02:27 PM

I have made it to this point: `graph.write_png('file_name.png')` At this point I received this `InvocationException: GraphViz's executables not found.` It went to the `\pydotplus\graphviz.pyc` location on my hard drive. It appears it found `graphviz`, but it said executables not found. What needs to happen for it to find the "executables"?? Is there a `graphviz.exe` file that needs to be placed somewhere or what? Thanks.

▲ 2 ↗ REPLY

Sri Sreshtan

05/11/2019 03:51 AM

Hello guys,

I am fairly new to the world of programming and coding. I tried to run a decision tree code in python in order to predict the financial distress of companies.

However as I was progressing in running the code, I got the following error: “ `ValueError: could not convert string to float: 'rev.ebit'.` ”

▲ 0 ↗ REPLY

Eve M

Want to leave a comment?

Anirban Ghosh

25/11/2019 06:19 PM

How to convert plot decision tree with multiple categorical variables..

▲ 1 REPLY**Mahesh Babu**

27/11/2019 09:49 PM

in this tutorial we are finding the final decision tree, how to figure out the label for unknown sample data?

▲ 1 REPLY**NS**

04/12/2019 12:40 AM

Can you give me a different between decision tree ID3 and C4.5 in python ?

▲ 1 REPLY**Wallace Wambugu**

10/12/2019 04:01 PM

Hi, I am having an issue with the `stringIO.external.SIX` from where we import `stringIO` it gives a deprecation warning: The module is deprecated in version 0.21 and will be removed in version 0.23 since we've dropped support for Python 2.7, do you have any suggestions of how to get around it?

▲ 1 REPLY**Gaurav Lal**

20/12/2019 03:21 AM

i am very new to machine learning , please explain

what is `value= []`, and `class represent`. say for example for a root node `glucose<=12.75`, `entropy =0.928`, `samples 537`, `values[354,183]`,`class 0`

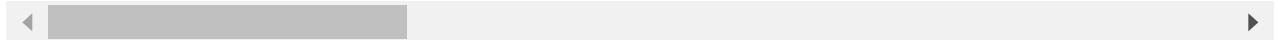
Want to leave a comment?

23/12/2019 12:08 AM

I have the next error with graphviz:

some idea??

```
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\externals\six.py:31: DeprecationWarning
  "(https://pypi.org/project/six/).", DeprecationWarning)
```



▲ 1 [REPLY](#)

A Dekker

17/01/2020 05:24 AM

It was really helpful, thanks! But in the end I got a syntax error about the 'graph' in the one last sentence. Can somebody maybe help me with solving this error?

▲ 0 [REPLY](#)

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