

# Data Science - Lecture 8

## Classification: Decision Trees

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# Classification: Definition

- Given a collection of records (*training set*)
  - Each record contains a set of *attributes*, one of the attributes is the *class*.
- Find a *model* for class attribute as a function of the values of other attributes.
- Goal: previously unseen records should be assigned a class as accurately as possible.
  - A *test set* is used to determine the accuracy of the model. Usually, the given data set is divided into training and test sets, with training set used to build the model and test set used to validate it.

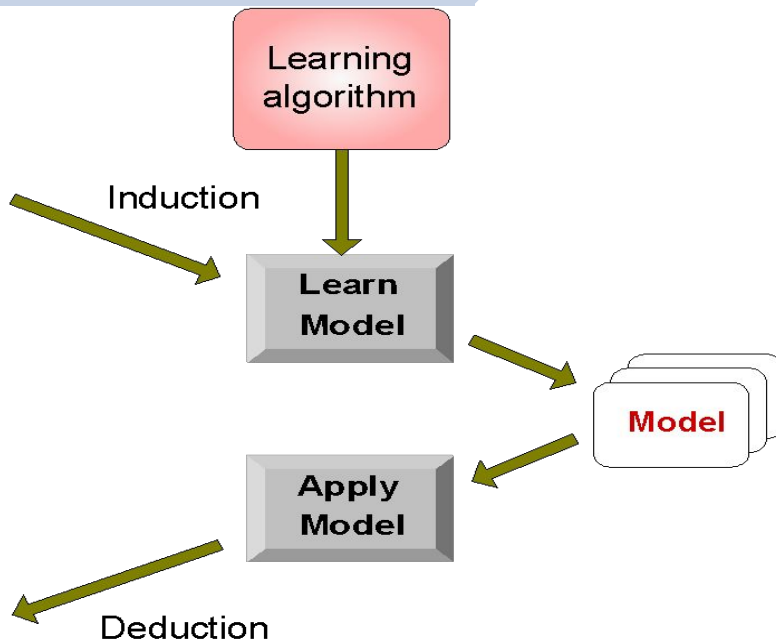
# Illustrating Classification Task

Tid	Attrib1	Attrib2	Attrib3	Class
1	Yes	Large	125K	No
2	No	Medium	100K	No
3	No	Small	70K	No
4	Yes	Medium	120K	No
5	No	Large	95K	Yes
6	No	Medium	60K	No
7	Yes	Large	220K	No
8	No	Small	85K	Yes
9	No	Medium	75K	No
10	No	Small	90K	Yes

Training Set

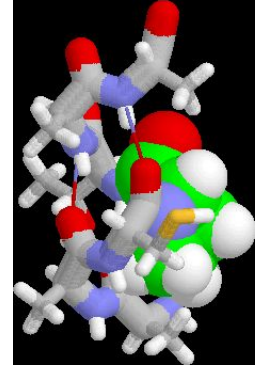
Tid	Attrib1	Attrib2	Attrib3	Class
11	No	Small	55K	?
12	Yes	Medium	80K	?
13	Yes	Large	110K	?
14	No	Small	95K	?
15	No	Large	67K	?

Test Set

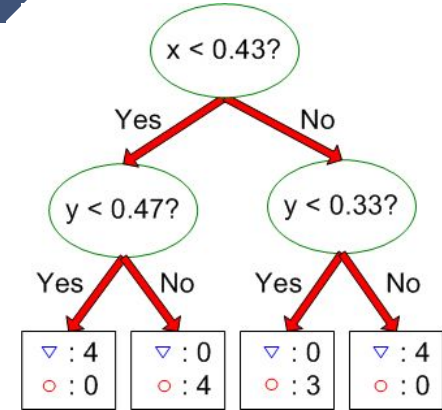
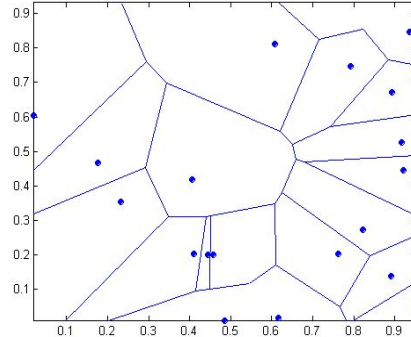
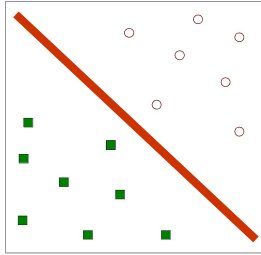


# Examples of Classification Task

- Predicting tumor cells as benign or malignant
- Classifying credit card transactions as legitimate or fraudulent
- Classifying secondary structures of protein as alpha-helix, beta-sheet, or random coil
- Categorizing news stories as finance, weather, entertainment, sports, etc



# Many different types of models



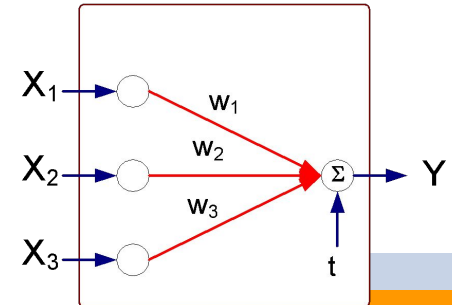
R1: (Give Birth = no)  $\wedge$  (Can Fly = yes)  $\rightarrow$  Birds

R2: (Give Birth = no)  $\wedge$  (Live in Water = yes)  $\rightarrow$  Fishes

R3: (Give Birth = yes)  $\wedge$  (Blood Type = warm)  $\rightarrow$  Mammals

R4: (Give Birth = no)  $\wedge$  (Can Fly = no)  $\rightarrow$  Reptiles

R5: (Live in Water = sometimes)  $\rightarrow$  Amphibians



# Metrics of Classifier Performance

- Focus on the predictive capability of a model
- Confusion Matrix:

ACTUAL CLASS	PREDICTED CLASS	
	Yes	No
Yes	TP	FN
No	FP	TN

TP (true positive)

FN (false negative)

FP (false positive)

TN (true negative)

- Most widely-used metric:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

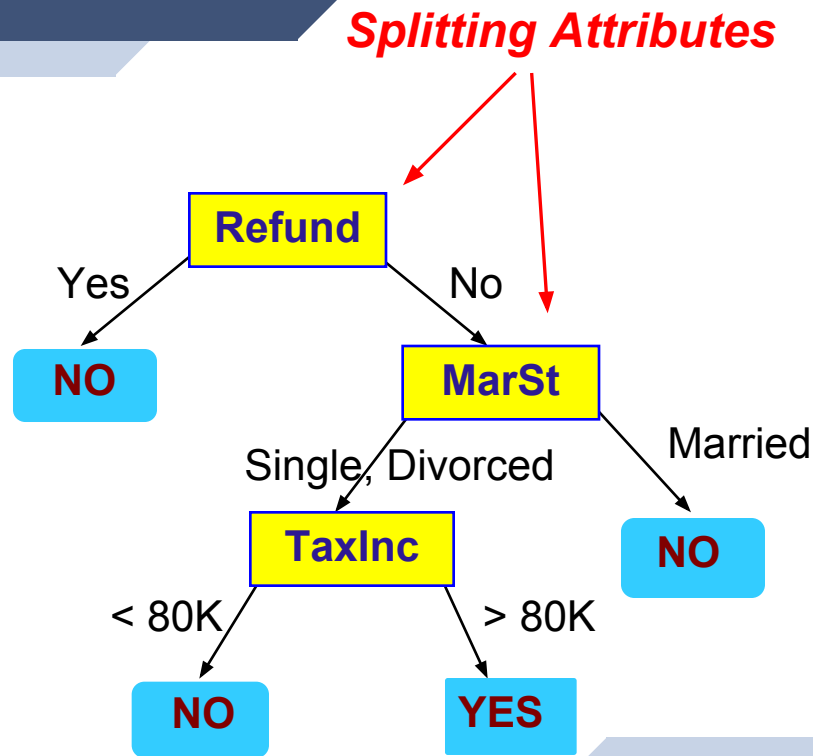
# Classification Techniques

- Decision Tree based Methods
- Rule-based Methods
- Memory based reasoning
- Neural Networks
- Naïve Bayes and Bayesian Belief Networks
- Support Vector Machines

# Example of a Decision Tree

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Training Data



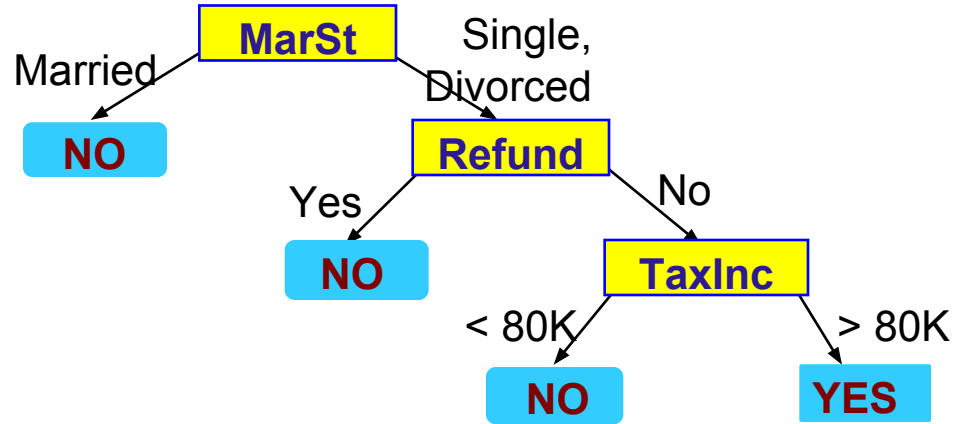
Model: Decision Tree



# Another Example of Decision Tree

*categorical* *categorical* *continuous* *class*

<i>Tid</i>	<i>Refund</i>	<i>Marital Status</i>	<i>Taxable Income</i>	<i>Cheat</i>
1	Yes	Single	125K	No
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6	No	Married	60K	No
7	Yes	Divorced	220K	No
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9	No	Married	75K	No
10	No	Single	90K	Yes



There could be more than one tree that fits the same data!

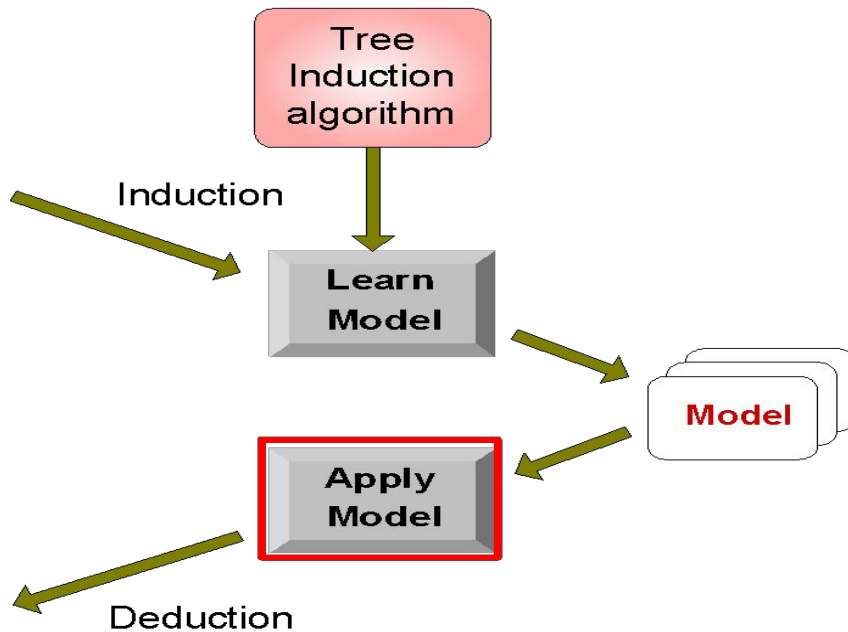
# Decision Tree Classification Task

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Training Set

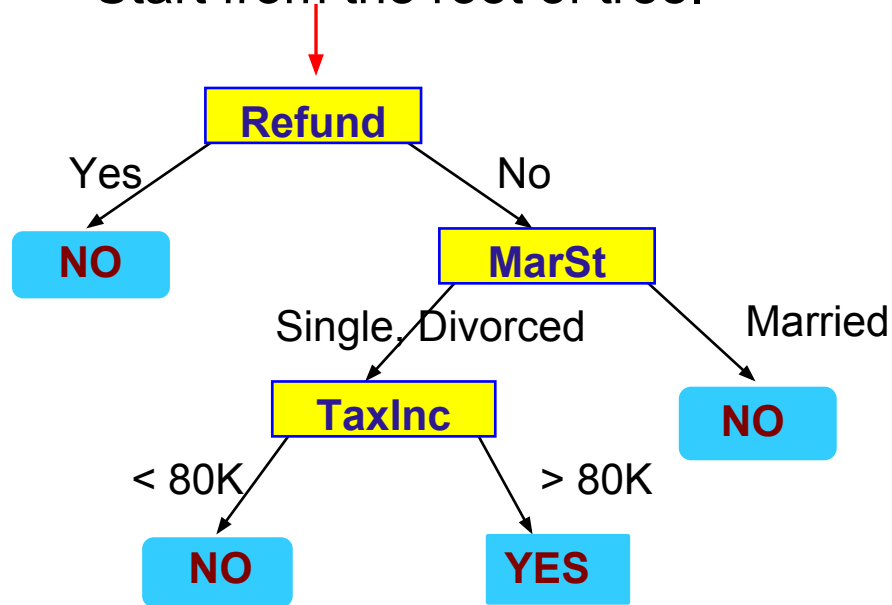
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Test Set



# Apply Model to Test Data

Start from the root of tree.



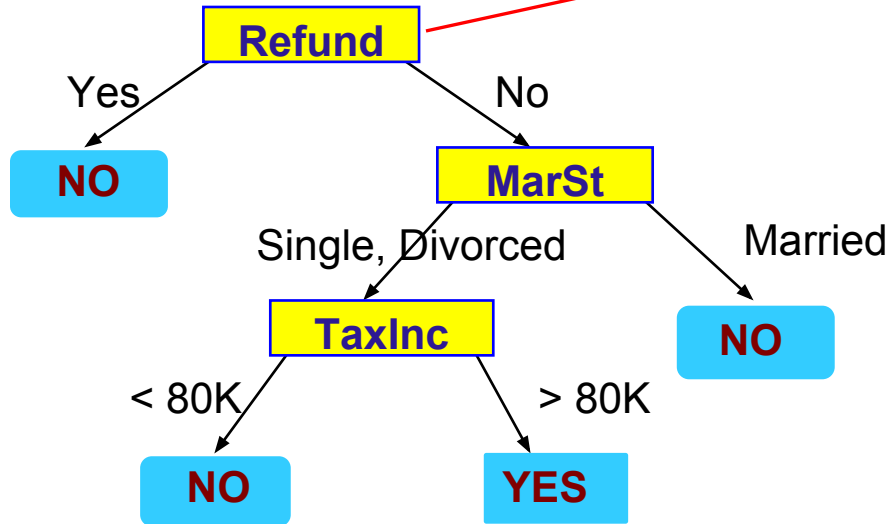
## Test Data

Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?

# Apply Model to Test Data

## Test Data

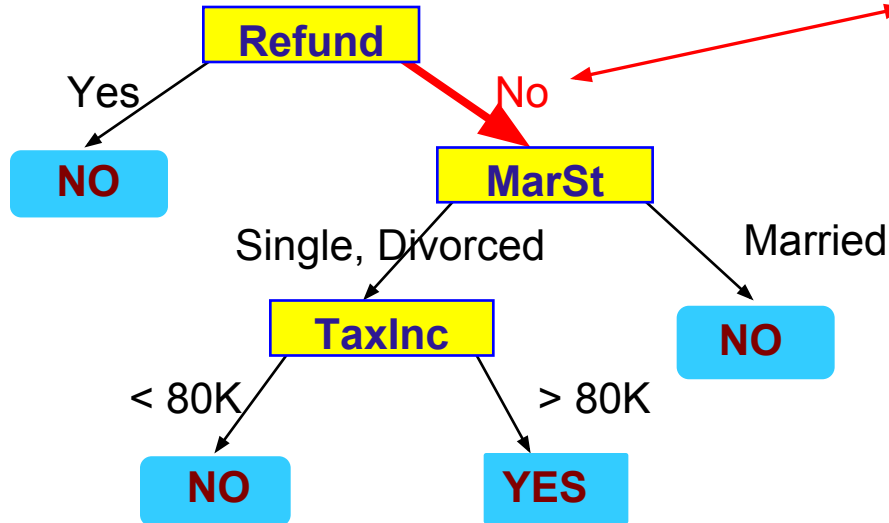
Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?



# Apply Model to Test Data

## Test Data

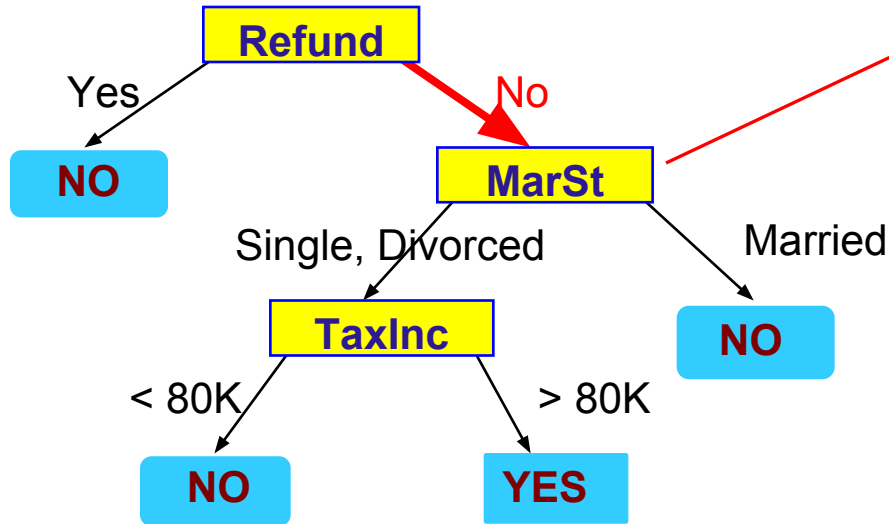
Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?



# Apply Model to Test Data

## Test Data

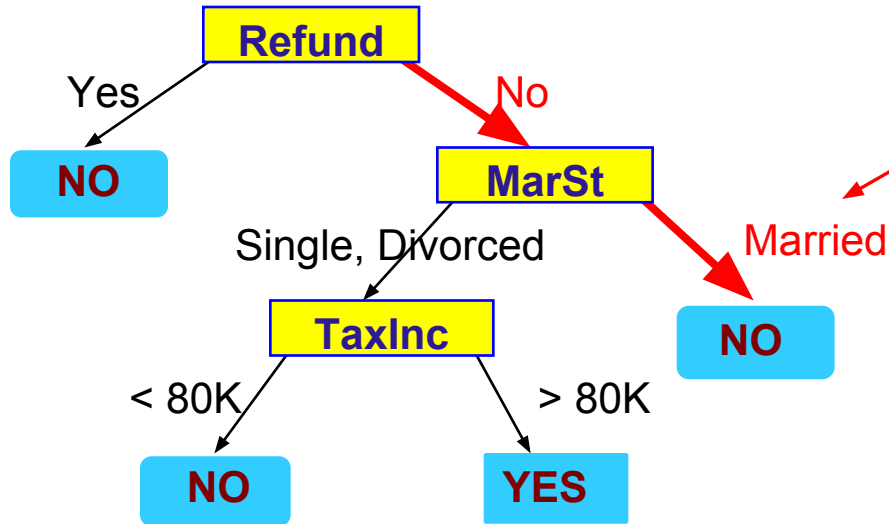
Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?



# Apply Model to Test Data

## Test Data

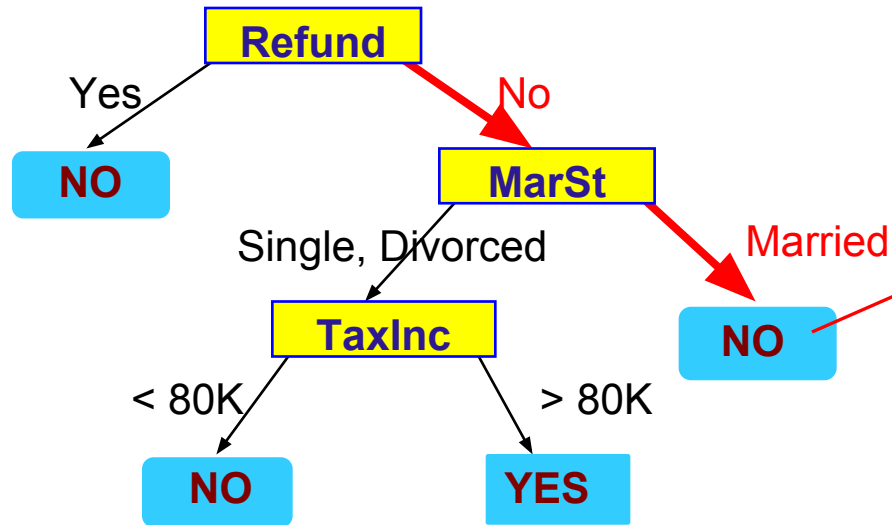
Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?



# Apply Model to Test Data

## Test Data

Refund	Marital Status	Taxable Income	Cheat
No	Married	80K	?



Assign Cheat to "No"



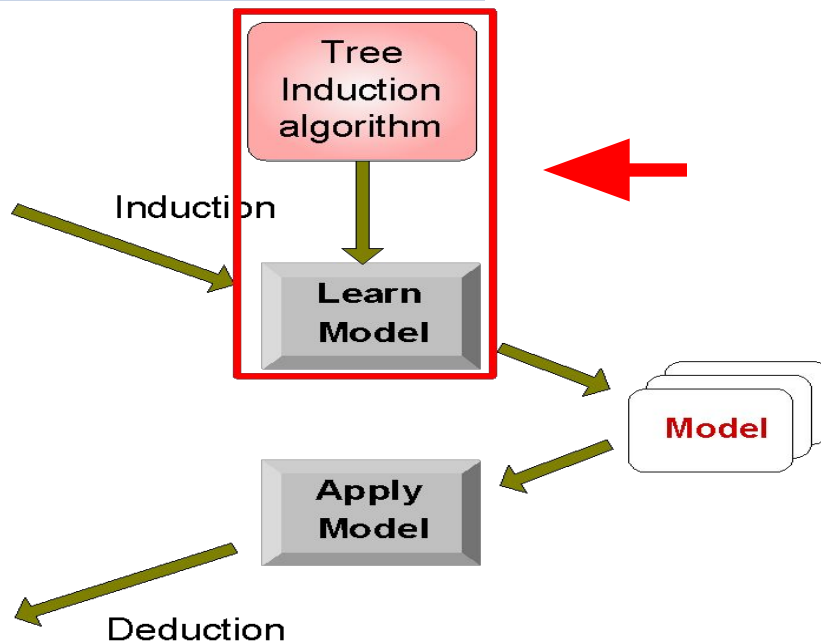
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Test Set



Decision  
Tree

# Decision Tree Induction Algorithms

Number of Algorithms:

- Hunt's
  - Hunt's Algorithm (1966)
- Quinlan's
  - Iterative Dichotomizer3 (1975) uses Entropy
  - C4.5 / 4.8 / 5.0 (1993) uses Entropy
- Brieman's
  - CART: Classification And Regression Trees (1984) uses Gini

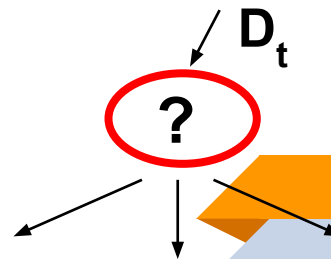
# Hunt's Algorithm

- In the Hunt's algorithm, a decision tree is grown in a recursive fashion by partitioning the training records successively into purer subsets

# General Structure of Hunt's Algorithm

- Let  $D_t$  be the set of training records that reach a node  $t$
- General Procedure:
  - If  $D_t$  contains records that belong to the same class  $y_t$ , then  $t$  is a leaf node labeled as  $y_t$
  - If  $D_t$  is an empty set, then  $t$  is a leaf node labeled by the default class,  $y_d$
  - If  $D_t$  contains records that belong to more than one class, use an attribute test to split the data into smaller subsets. Recursively apply the procedure to each subset.

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# General Structure of Hunt's Algorithm

**Input:** Dataset D

**Output:** Decision tree t

**Induce(D):**

If all tuples t in D have label + then  
return

If all tuples t in D have label - then  
return

For **all split criteria C**:

$$D_{1,C} = \{ t \text{ in } D \mid t \text{ satisfies } C \}$$

$$D_{2,C} = D - D_{1,C}$$

**Measure Quality**( $D_{1,C}, D_{2,C}$ )

Let C be the best split

Return

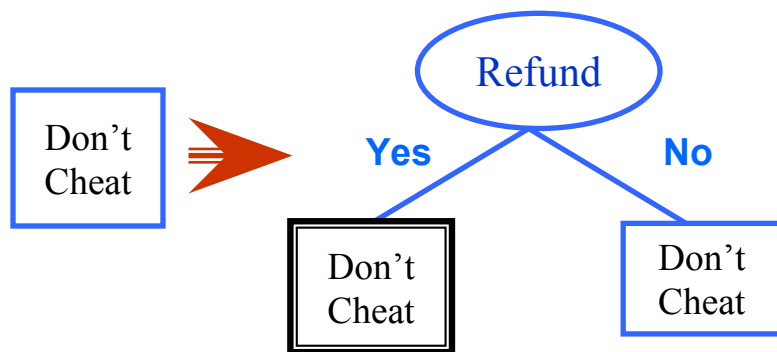
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# Hunt's Algorithm

Don't  
Cheat

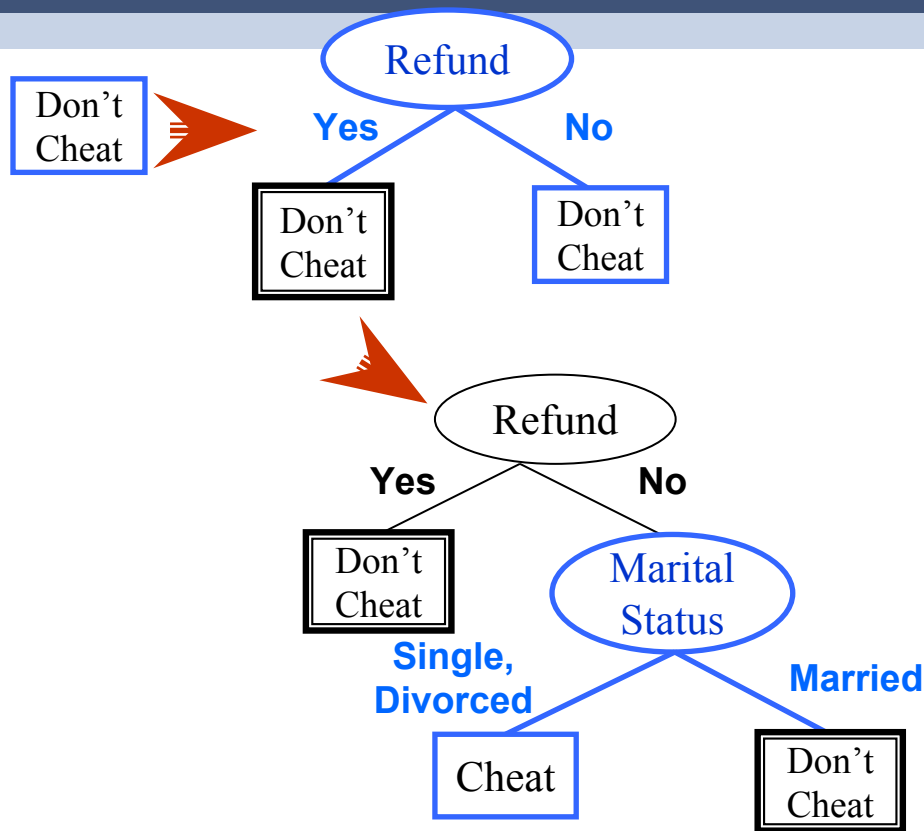
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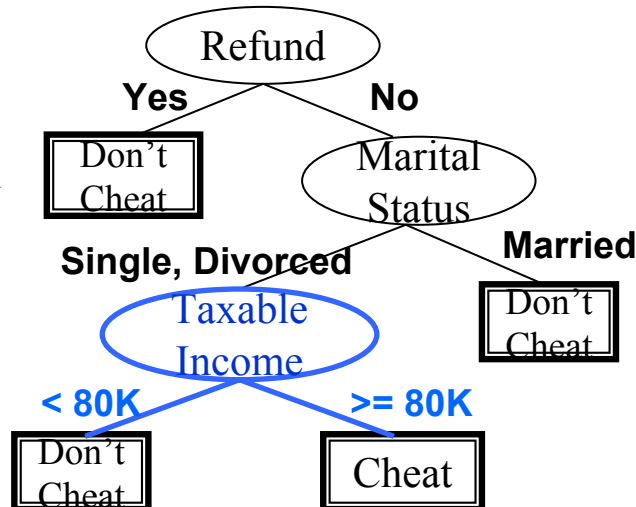
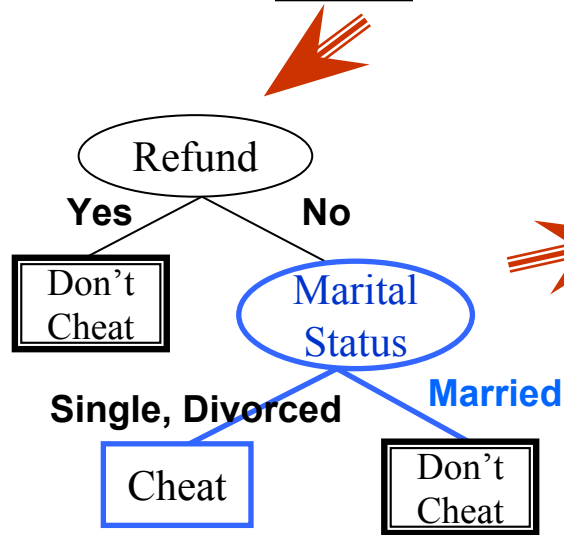
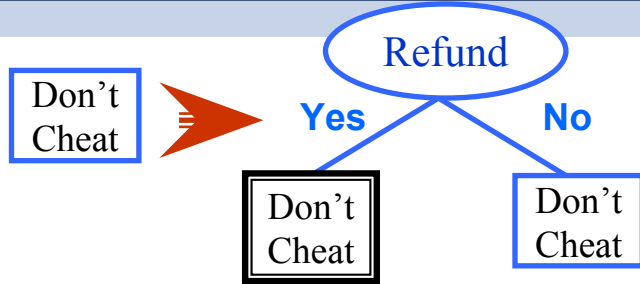
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