

# **Classification Lecture Notes (2)** **(cse352)**

**Review, Training, Testing, Predictive  
Accuracy**

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# Classification Data

- **Data format:** a data table with key attribute removed. Special attribute- class attribute must be distinguished

age	income	student	credit_rating	buys_computer
<=30	high	no	fair	no
<=30	high	no	excellent	no
30...40	high	no	fair	yes
>40	medium	no	fair	yes
>40	low	yes	fair	yes
>40	low	yes	excellent	no
31...40	low	yes	excellent	yes
<=30	medium	no	fair	no
<=30	low	yes	fair	yes
>40	medium	yes	fair	yes
<=30	medium	yes	excellent	yes
31...40	medium	no	excellent	yes
31...40	high	yes	fair	yes
>40	medium	no	excellent	no

# Classification (Training ) Data with objects

rec	Age	Income	Student	Credit_rating	Buys_computer (CLASS)
r1	<=30	High	No	Fair	No
r2	<=30	High	No	Excellent	No
r3	31...40	High	No	Fair	Yes
r4	>40	Medium	No	Fair	Yes
r5	>40	Low	Yes	Fair	Yes
r6	>40	Low	Yes	Excellent	No
r7	31...40	Low	Yes	Excellent	Yes
r8	<=30	Medium	No	Fair	No
r9	<=30	Low	Yes	Fair	Yes
r10	>40	Medium	Yes	Fair	Yes
r11	<=30	Medium	Yes	Excellent	Yes
r12	31...40	Medium	No	Excellent	Yes
r13	31...40	High	Yes	Fair	Yes
r14	>40	Medium	No	Excellent	No

# CHARACTERISTIC DESCRIPTIONS (Review)

## ***Example:***

- Some of the ***characteristic descriptions*** of the concept **C** with description: **buys\_computer= no** are
  - Age= $\leq$  30 & income=high & student=no & credit\_rating=fair
  - Age= $>$ 40& income=medium & student=no & credit\_rating=excellent
  - Age= $>$ 40& income=medium
  - Age= $\leq$  30
  - student=no & credit\_rating=excellent

# Characteristic Formula (Review)

Any formula (of a proper language) of a form

**IF** concept description **THEN** characteristics

is called a characteristic formula

**Example:**

- **IF** buys\_computer= no **THEN** income = low & student=yes & credit=excellent
- **IF** buys\_computer= no **THEN** income = low & credit=fair

# Characteristic Rule (Review)

- A characteristic formula

**IF** concept description **THEN** characteristics

is called **a characteristic rule** (for a given database)

if and only if it is **TRUE** in the given database, i.e.

**$\{r: \text{concept description}\} \wedge \{r: \text{characteristics}\} = \text{not empty set}$**

# Characteristic Rule (Review)

## EXAMPLE:

The formula

- IF buys\_computer= no THEN income = low & student=yes & credit=excellent

is a characteristic rule for our database because

$\{r: \text{buys\_computer} = \text{no}\} = \{r1, r2, r6, r8, r16\},$

$\{r: \text{income} = \text{low} \ \& \ \text{student} = \text{yes} \ \& \ \text{credit} = \text{excellent}\} = \{r6, r7\}$

and

$\{r1, r2, r6, r8, r16\} \wedge \{r6, r7\} = \text{not emptyset}$

# Characteristic Rule (Review)

## EXAMPLE:

The formula

- IF buys\_computer= no THEN income = low & credit=fair

Is NOT a characteristic rule for our database because

$\{r: \text{buys\_computer} = \text{no}\} = \{r1, r2, r6, r8, r16\},$

$\{r: \text{income} = \text{low} \ \& \ \text{credit} = \text{fair}\} = \{r5, r9\}$

and

$\{r1, r2, r6, r8, r16\} \wedge \{r5, r9\} = \text{emptyset}$



# Discrimination (Review)

- *Discrimination is the process which aim is to find rules that allow us to **discriminate** the objects (records) belonging to a given concept (one class ) from the rest of records ( classes)*
- **DISCRIMINANT RULES** have a form:

***If characteristics then concept***

*Example*

- ***If*** Age= $\leq$  30 & income=high & student=no & credit\_rating=fair  
***then*** buys\_computer= no

# Discriminant Formula

*A discriminant formula is any formula*

***If characteristics then concept***

- Example:
- IF Age=>40 & inc=low THEN buys\_comp= no

# Discriminant Rule (Definition)

- A discriminant formula

***If characteristics then concept***

is a ***DISCRIMINANT RULE*** (in a given database)

*iff*

***{r: Characteristic}  $\sqsubseteq$  {r: concept}***

# Discriminant Rule

- **Example:**

- *A discriminant formula*

**IF Age=>40 & inc=low THEN buys\_comp=  
no**

***IS NOT a discriminant rule*** in our data base  
*because*

*{o: Age=>40 & inc=low} = {o5, o6} is not a  
subset of the set {o:buys\_comp=no} = {o1,  
o2, o6, o8, o14}*

# Characteristic and discriminant rules

- The inverse implication to the characteristic rule is usually NOT a discriminant rule
- Example : the inverse implication to our characteristic rule: ***If*** buys\_computer= no **then** income = low & student=yes & credit=excellent

is:

- ***If*** income = low & student=yes & credit=excellent **then** buys\_computer= no
- The above rule is NOT a discriminant rule as it can't discriminate between concept with description buys\_computer= no and buys\_computer= yes
- (see records r6 and r8 in our training dataset)

# Supervised Learning Goal (1)

- Given a data set and a concept (class) **c** defined in this dataset **FIND a minimal set (or as small as possible set) characteristic, and/or discriminant rules, or other descriptions** for the concept **c**, or class, or classes.

## Supervised Learning Goal (2)

- We also want these rules to involve as few attributes as it is possible, i.e. we want the rules to have **as short as possible length of descriptions.**

# Supervised Learning Classification Learning

- The process of creating discriminant and/or characteristic rules and TESTING them
- is called a **learning process**, and when it is finished we say that the concept (class) has been learned (and tested) from examples (records in the dataset that form the the TRAINING set)).
- It is called **a supervised learning** because we know the concept description for all examples in the training and test set.

# A FULL SET OF DISCRIMINANT RULES for our Training Dataset (Obtained by the Decision Tree Algorithm)

- The rules are:

IF *age* = “<=30” AND *student* = “no” THEN *buys\_computer*  
= “no”

IF *age* = “<=30” AND *student* = “yes” THEN *buys\_computer*  
= “yes”

IF *age* = “31...40” THEN  
*buys\_computer* = “yes”

IF *age* = “>40” AND *credit\_rating* = “excellent” THEN  
*buys\_computer* = “no”

IF *age* = “<=30” AND *credit\_rating* = “fair” THEN  
*buys\_computer* = “yes”

# Rules testing

- In order to use rules for testing, and later when testing is done and predictive accuracy is acceptable we write rules in a **predicate form**:

IF *age*( x,  $\leq 30$ ) AND *student*(x, no) THEN

*buys\_computer* (x, no)

IF *age*(x,  $\leq 30$ ) AND *student* (x, yes) THEN

*buys\_computer* (x, yes)

- Attributes and their values of the new record x are matched with the IF part of the rule and the record is classified accordingly to the THEN part of the rule.

# Example of a TEST Data for our TRAINING set

rec	Age	Income	Student	Credit_rating	Buys_computer(CLASS)
r1	<=30	Low	No	Fair	yes
r2	<=30	High	yes	Excellent	No
r3	<=30	High	No	Fair	Yes
r4	31...40	Medium	yes	Fair	Yes
r5	>40	Low	Yes	Fair	Yes
r6	>40	Low	Yes	Excellent	yes
r7	31...40	High	Yes	Excellent	Yes
r8	<=30	Medium	No	Fair	No
r9	31...40	Low	no	Excellent	Yes
r10	>40	Medium	Yes	Fair	Yes

# Test dataset and Predictive Accuracy

- The Test Dataset has the same format as the training dataset, i.e. the values of concept attribute are known
- We use it to evaluate the predictive accuracy of our set of rules (discovered by a classification algorithm)
- **PREDICTIVE ACCURACY** of the set of rules, or any classification algorithm is **a percentage of correctly classified data** in the testing dataset.
- If the predictive accuracy is not high enough, or far too high we chose a different learning and testing datasets and start process again
- There are many methods of testing the rules and they will be discussed later

# Correctly and Not Correctly Classified Records

- A Record is **correctly classified** if and only if the following conditions hold:
  - (1) we **can classify** the record, i.e. there is a rule such that its LEFT side matches the record,
  - (2) **classification determined by the rule is correct**, i.e. the RIGHT side of the rule matches the value of the record class attribute,

OTHERWISE

- The record is **not correctly classified**
- **WORDS USED: not correctly = incorrectly = misclassified**

# Exercise 1

- Assume that we have a following set of rules:
- R1:  $a1=1 \wedge a2=0 \Rightarrow \text{class}=\text{yes}$
- R2:  $a1=0 \wedge a2=3 \Rightarrow \text{class}=\text{no}$
- R3:  $a2=1 \Rightarrow \text{class}=\text{yes}$
- The TEST data has the following 6 records, where the attributes are a1, a2, class
- $r1 = (1, 0, \text{yes})$ ,  $r2 = (0, 3, \text{yes})$ ,  $r3 = (1, 1, \text{no})$ ,  
 $r4 = (2, 1, \text{yes})$ ,  $r5 = (3, 1, \text{yes})$ ,  $r6 = (1, 2, \text{no})$

**CALCULATE** the Predictive Accuracy of this set of rules with respect to the above TEST data of 6 records.

## Exercise 2

- Evaluate the Predictive Accuracy of the set of rules:

R1: IF *age* = “<=30” AND *student* = “no” THEN *buys\_computer* = “no”

R2: IF *age* = “<=30” AND *student* = “yes” THEN *buys\_computer* = “yes”

R3: IF *age* = “31...40” THEN  
*buys\_computer* = “yes”

R4: IF *age* = “>40” AND *credit\_rating* = “excellent” THEN  
*buys\_computer* = “no”

R5: IF *age* = “<=30” AND *credit\_rating* = “fair” THEN  
*buys\_computer* = “yes”

with respect to the TEST data on the next slide .

# TEST DATA for Example 2

rec	Age	Income	Student	Credit_rating	Buys_computer(CLASS)
r1	<=30	Low	No	Fair	yes
r2	<=30	High	yes	Excellent	No
r3	<=30	High	No	Fair	Yes
r4	31...40	Medium	yes	Fair	Yes
r5	>40	Low	Yes	Fair	Yes
r6	>40	Low	Yes	Excellent	yes
r7	31...40	High	Yes	Excellent	Yes
r8	<=30	Medium	No	Fair	No
r9	31...40	Low	no	Excellent	Yes
r10	>40	Medium	Yes	Fair	Yes

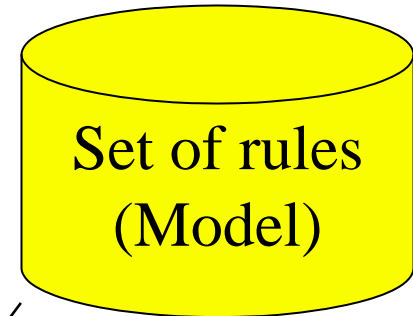
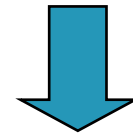
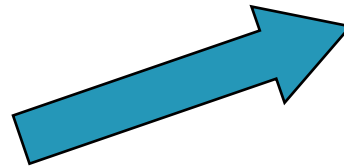
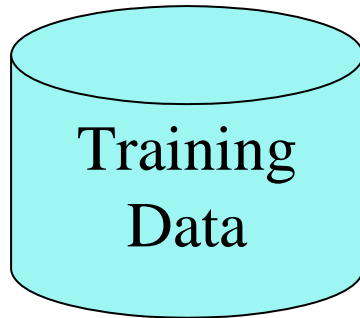
# Classification and Classifiers

- An algorithm (model, method) is called a **classification algorithm** if it uses the data and its classification to build a set of patterns: discriminant and /or characteristic rules or other pattern descriptions. Those patterns are structured in such a way that we can use them **to classify unknown sets of objects**- unknown records.
- For that reason, and because of the goal a classification algorithm is often called shortly a **classifier**.
- The name **classifier** implies more than just classification algorithm.
- **A classifier is a final product of the data set and a classification algorithm.**

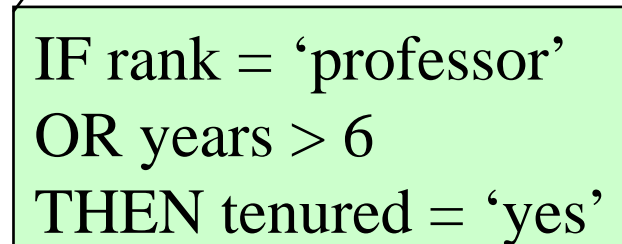
# Classification and Classifiers

- Building a classifier consists of two phases:  
**training and testing.**
- In both phases we use data (**training data set** and disjoint with it **test data set**) for which the class labels are known for ALL of the records.
- **We use** the training data set to create patterns (rules, trees, or to train a Neural or Bayesian network).
- **We evaluate** created patterns with the use of of test data, which classification is known.
- The measure for a trained classifier accuracy is called **predictive accuracy.**
- **The classifier is build** i.e. we terminate the process if it has been trained and tested and predictive accuracy was on an acceptable level.

# Training: a Classifier Construction

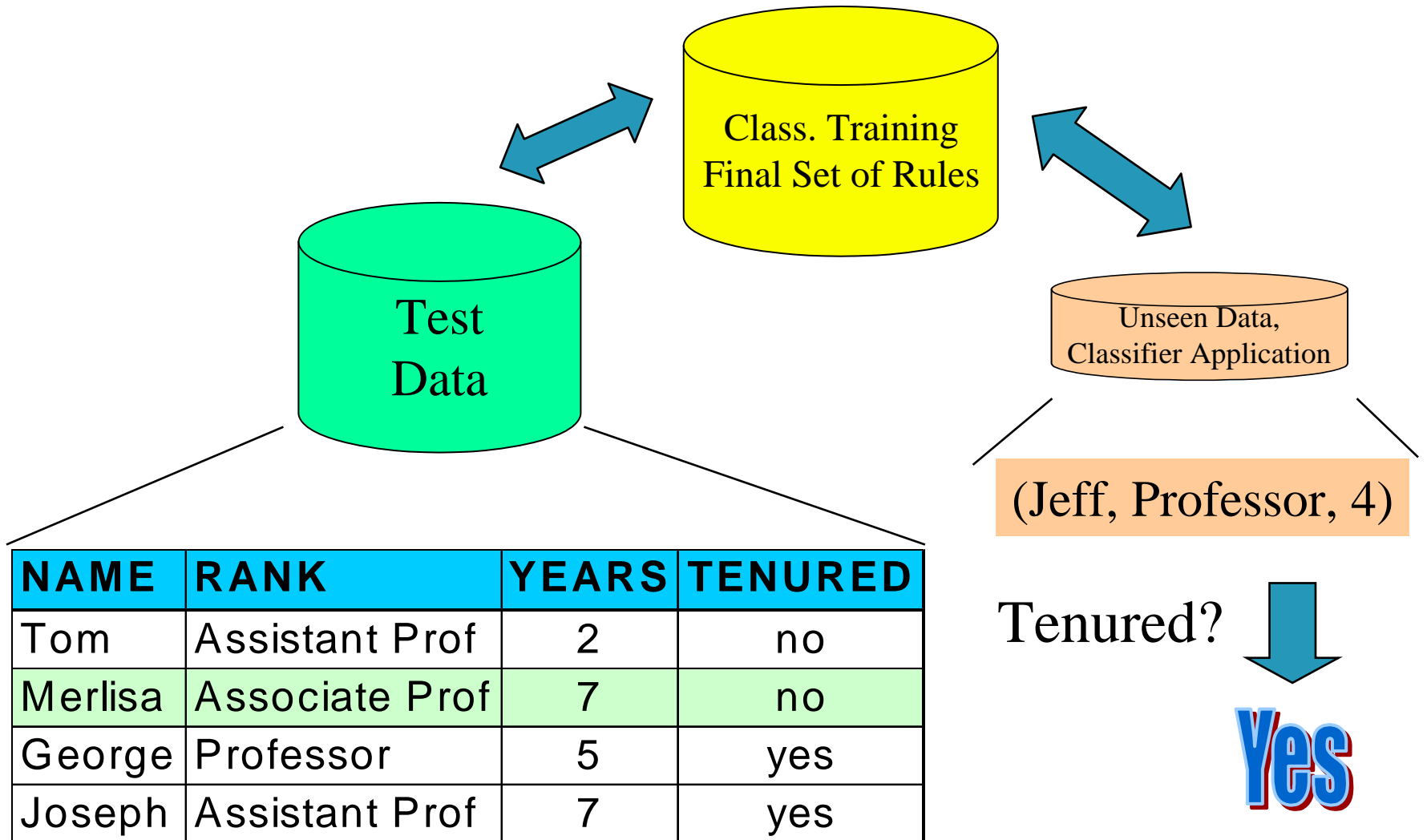


NAME	RANK	YEARS	TENURED
Mike	Assistant Prof	3	no
Mary	Assistant Prof	7	yes
Bill	Professor	2	yes
Jim	Associate Prof	7	yes
Dave	Assistant Prof	6	no
Anne	Associate Prof	3	no



IF rank = 'professor'  
OR years > 6  
THEN tenured = 'yes'

# Testing and Prediction (use of trained classifier)



# Classifiers Predictive Accuracy

- **PREDICTIVE ACCURACY** of a classifier is a percentage of well classified data in the testing data set.
- **Predictive accuracy depends heavily on a choice of the test and training data.**
- There are many methods of choosing test and training sets and hence evaluating the predictive accuracy. This is a separate field of research.

# Predictive Accuracy Evaluation

The main methods of predictive accuracy evaluations are (see slides: Classifier Testing):

- **Re-substitution** ( $N ; N$ )
- **Holdout** ( $2N/3 ; N/3$ )
- **x-fold cross-validation** ( $N-N/x ; N/x$ )
- **Leave-one-out** ( $N-1 ; 1$ ),

where  $N$  is the number of instances in the dataset (see the separate presentation)

- The process of building and evaluating a classifier is also called a **supervised learning**, or lately when dealing with large data bases a classification method in **Data Mining**.